ISSN 0096-4158

THE MARYLAND NATURALIST

Volume 46, Number 1 Summer 2003

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A BIANNUAL PUBLICATION OF THE NATURAL HISTORY SOCIETY OF MARYLAND

The Maryland Naturalist

A Biannual Publication of the Natural History Society of Maryland

Managing Editor
Joel W. Snodgrass
The Maryland Naturalist
Department of Biological Sciences
Towson University
Towson, MD 21252, USA

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Published by the Natural History Society of Maryland, Inc.
2643 North Charles Street
Baltimore, MD 21218, USA
410-235-6116
www.marylandnature.org

Printed by Cadmus Journal Services
Linthicum, MD 21090, USA

The Maryland Naturalist 46(1):1–15 Summer 2003

Life History and Status of the Mountain Chorus Frog (*Pseudacris brachyphona*) In Maryland

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Abstract.—During the springs of 1996-1999 we spent 14 weeks searching for mountain chorus frogs, *Pseudacris brachyhona*, in the Appalachian mountains of western Maryland. During 1996, we visited all historic breeding sites recorded in the database of the Wildlife and Heritage Division of the Maryland Department of Natural Resources, but despite this effort we were able to locate only one breeding congress comprised of 17 adults—eight males and nine females. No additional sites were located during less intensive surveys in 1997-1999. Males comprising our focal population vocalized from an isolated segment of the available reproductive habitat, and mating success was non-random. Three temporal properties of the call (length, pulses/second, and calls/min) were significantly influenced by temperature, and a single spectral property (pitch) was inversely correlated with male body mass. Collectively, nine females laid 978 eggs, most of which hatched. By late May, > 600 tadpoles were still present at the site. However, during early June destructive thunderstorms buffeted the region and torrential runoff scoured the breeding site killing all tadpoles. Although mountain chorus frogs utilized the same site during 1997, the mean size of the males was significantly smaller and fewer eggs were deposited. These between year differences indicate a high annual turn over in the breeding population and suggest that a lack of recruitment over two consecutive seasons could result in extirpation of the population. The decline of the mountain chorus frogs within the geopolitical boundaries that define Maryland is significant, not because it decreased the faunal diversity of a small eastern state, but because it brings into focus the more serious problem of amphibian declines on a global scale.

Introduction

The mountain chorus frog (*Pseudacris brachyphona*) is a terrestrial member of the anuran family Hylidae. The species is indigenous to forested slopes and hilltop habitats along the Appalachian Mountains from Alabama in the south, to Pennsylvania in the north, and reaches the northeast corner of Mississippi in the west (Wright and Wright 1949; Conant and Collins 1998). Disjunct populations are also recorded in southwestern North Carolina and adjacent portions of Georgia and Tennessee (Hoffman 1980; Conant and Collins 1998).

The mountain chorus frog is common throughout much of its range, and based on historical records, *P. brachyphona* was once known from widely distributed localities in Allegany and Garrett counties on the Appalachian Plateau of Maryland (Fig. 1). By 1970, the species was in significant decline within the state, and a number of historic sites no longer supported viable populations of this diminutive hylid (Harris

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Figure 1. Map depicting the historic range of the mountain chorus frog (*Psuedacris brachyphona*) within the geopolitical boundaries of Maryland. Dark circles refer to historic localities. (Modified from Harris 1975).

1975). Today, the species is listed as "threatened" by the Maryland Department of Natural Resources (Maryland Wildlife and Heritage Division, 2001).

Because of their confinement to forested habitats in rural Appalachia, and their tendency to breed during the late winter or early spring immediately following snow melt, few studies have been published on the life history of mountain chorus frogs. The most notable exceptions are Barbour (1958), Green (1938, 1964) and Thompson and Martof (1957). Each of these studies was of limited scope and focused on local populations in Kentucky, southern West Virginia and Georgia, respectively.

The primary purpose of our investigation was to assess the status of the mountain chorus frog at each of the nine historical sites of occurrence recorded in the Maryland Wildlife and Heritage Division database, and to search for additional localities of occurrence in Allegany and Garrett counties (the westernmost counties of Maryland's montane panhandle). A secondary goal of the study was to provide quantitative information on male calling behavior and mating success, as well as female egg deposition and larval development for a population on the extreme northeastern edge of the species range.

Methods

Search Protocol

To accurately assess the status of the mountain chorus frog within the geopolitical boundaries of Maryland, we devoted twelve weeks to a comprehensive search of Allegany and Garrett counties during the spring of 1996. During this period (April 1–June 30) we logged more than 5000 road miles. Our search protocol involved making a minimum of three visits to each of the nine historical localities. Typically a

site was visited twice after dark (to monitor calling activity) and once during the day (to search for egg masses). At each site, we recorded the presence or absence of frogs, the width and depth of the site, and current velocity (Swoffer 2100 Current Meter). In addition, we conducted amphibian calling surveys along rural back roads and adjacent to extensive montane wetlands (known locally as glades) following the United States Geological Survey (USGS) North American Amphibian Monitoring Program (NAAMP) protocol (http://www.mp2-pwrc.usgs.gov/NAAMP/volunteer/). We made 12 additional visits to the Alleghany Plateau during the 1997–1999 breeding seasons in order to monitor the status of the only active breeding site located during 1996.

Male Advertisement Behavior

During the spring of 1996 the Savage River State Forest population was composed of eight males. Each male was collected by hand and a small, labeled flag was placed at the point of capture. Males were weighed to the nearest 0.1 g using a Pesola spring scale (5 g) before being outfitted with a uniquely lettered waistband. Waistbands were constructed from plastic embossing tape and embroidery thread after Forester and Thompson (1998). Once a male had been processed, it was returned to its point of capture. We elected to collect body mass measurements rather than snout-urostyle length (SUL) since the former measurement may be accomplished quickly in the field, inflicts minimal trauma to the animal being measured, and is a more accurate indicator of male body size (based on the repeatability of measurements made by all three authors).

Each of the males marked during 1996 were tape-recorded with a Sony Professional Walkman (WM-D6C) equipped with a Sennheiser shotgun microphone (ME 80 head attached to K3 power module). Tape recordings were analyzed in a field laboratory located in the Savage River State Forest headquarters using an Apple Macintosh (SE-30) running Canary 1.0 software (Cornell University). During a recording session, we held the microphone approximately 0.5 m from the focal male and recorded 5 to10 calls. We also recorded the root mean square (RMS) intensity of each calling male in decibels (dB) using a precision integrating sound level meter (Brüel & Kjær 2230). During call analysis, we calculated three temporal properties of the call: (1) call length in milliseconds (msec), pulses per second (pps) and (3) pulses per call (ppc). In addition, we calculated one spectral property: frequency (KHz). In all cases, five calls were analyzed for each male and the values averaged for between male comparisons. Because each of these call parameters is potentially influenced by the frog's body temperature, we needed to know the body core temperature of males during a given recording session. Unfortunately, due to their small size and the rate of heat transfer from the investigator to the frog, it was not practical to record cloacal temperatures. Instead, we used a fast reading, cloacal thermometer (Miller and Weber, Inc.) to record the water temperature, substrate temperature, and the air temperature at each calling site. Because the body core temperature of is likely influenced by each of the media to which a frog is exposed at any point in time (e.g., water, air, substrate), we calculated weighted temperature values for each male. If a male was calling while sitting in water with two-thirds of his body immersed, we calculated his temperature by averaging three values (water temperature + water temperature + air temperature). If a male was sitting on land, we also averaged three temperatures (substrate

temperature + air temperature + air temperature). We contend that these weighted temperature values more closely approximate the actual core temperatures of the frogs. A contention supported by data for gray treefrogs (*Hyla versicolor*) in which weighted temperature values closely approximated actual cloacal temperatures (Forester, unpublished).

We used regression analysis to examine the relationship between temperature and each of the call parameters outlined above. In order to compare the calls of males recorded over a wide range of temperatures (1.5–18°C), we adjusted each call to 11°C. One of the parameters, calling rate, violated the assumptions of the linear model and as a consequence calls per minute were log transformed.

There is an inverse correlation between call frequency (pitch) and male body size (Forester 1973, 1985; Gerhardt 1988). We used Pearson's correlation analysis to examine this relationship between body size and pitch as well as the relationship between body size and three temporal properties of the advertisement call: length in milliseconds, number of pulses and pulses per second (pps).

Egg Deposition and Development

During 1996 breeding season, we searched the Savage River State Forest breeding site each morning, Monday through Friday. When a cluster of eggs was located, its position was marked with a small flag. We then recorded depth of the cluster, length and width of the cluster (mm), number of eggs it contained and their developmental stage (Gosner 1960).

We isolated three amplexed pairs of mountain chorus frogs in separate opaque jars (4–L) containing 2.54 cm of spring water. After 8 h we counted the number of clusters and the total number of eggs deposited by each female before returning them to the breeding site. Since we were interested in collecting baseline data on the development of *P. brachyphona* tadpoles, and because embryos developing in the field are subjected to a heterogeneous thermal environment, we transported one egg mass to Towson University where it was maintained in a controlled environment room and monitored daily.

RESULTS

Breeding Site Characteristics

During 1996, we were able to locate five of the nine historical localities. Of these, only one (Savage River State Forest—Site A) supported a breeding congress of *P. brachyphona*. Sites designated as the "CCC Camp in Swanton" and "LaVale, MD" were impacted or destroyed by the construction of the Maryland Training School for Boys and the LaVale Mall, respectively. We surveyed the woodlands adjacent to the historic CCC Camp Road but did not observe suitable habitat, nor did we hear calling males. There were numerous ditches and standing water on the periphery of the LaVale Mall, and while they supported populations of spring peepers (*Psuedacris crucifer*) and American toads (*Bufo americanus*), mountain chorus frogs were not present. The descriptions of the two remaining historical sites (Jennings, MD and Friendsville, MD) were so vague that we could not be certain of their locations. The "Jennings" locality abounded with potential breeding sites, but no breeding activity

was noted (even during the peak of the breeding season). We observed several suitable breeding sites on County Road 53 between Friendsville, MD and the Pennsylvania state line. Although devoid *of P. brachyphona*, several supported robust populations of *P. crucifer*.

Each of the extant historical breeding sites in Maryland may be characterized as a shallow roadside ditch (typically < 1m in width, and ranging in depth from 1–38 cm). In all sites (except the LaVale Mall) there was a gentle current flowing through the site.

The Savage River State Forest site may be characterized as a shallow ditch positioned at the base of a steep hillside, < 3 m from the edge of a paved county road. Over the course of our study, the ditch had a maximum width of 1 m, and ranged from 1–15 cm in depth. During 1996, the current was recorded as 0.3 m/sec. Although suitable habitat appeared to extend for more than 150 m, frogs were concentrated within the same 10 m segment of the site during four consecutive years (1996–99).

During the early spring, the site was devoid of vegetation, but did contain a thick layer of submerged leaf litter. This leaf litter provided cover for the developing tadpoles as well as a substrate upon which algae (a primary larval food source) could grow. By late spring and early summer, grasses overgrew the site providing shade for developing larvae during a portion of the day. Nevertheless, the site was frequently exposed to intensive sunlight as well as potentially harmful runoff from the road in the form of road salt and petroleum byproducts.

During much of the spring, the site was largely free of competitors. During 1996, juvenile pickerel frogs (*Rana palustris*), juvenile green frogs (*Rana clamitans*) and a few adult spring peepers invaded the site for brief periods. The competitive impact of these species on resident mountain chorus frogs is unknown, but appeared to be minimal. Female spring peepers were never observed at the site (1996–98), and as a consequence, we concluded that larval competition was either low or non-existent.

During the spring and early summer of 1996, and again during the spring of 1998 we observed predaceous snakes at the site: (1) Eastern Gartersnake (*Thamnophis s. sirtalis*) and (2) Northern Watersnake (*Nerodia s. sipedon*). We did not observe snake predation upon resident mountain chorus frogs during either year, but due to the aggregated nature of the breeding congress and the fact that some tagged males disappeared from the site after only one or two observations, we can not rule it out.

Male Advertisement Call

The advertisement call of a typical *P. brachyphona* male is graphically presented in Figure 2. The call may be described as a nasal trill with a dominant frequency of 2.1 KHz; it contains 24 pulses and lasts 220 msec. Three temporal parameters of the mountain chorus frog advertisement call, length (msec), pulses per second (pps) and the number of calls per minute (cpm) were significantly influenced by temperature (Fig. 3). The calls of eight males have been adjusted to 11°C for comparison (Table 1). Call frequency (KHz) and intensity (dB) were not influenced significantly by temperature but are also included in Table 1.

Sexually mature, calling males exhibited variation in body mass within and between seasons. Over a two-year period (1996-97), we captured and weighed 18 males from the Savage River State Forest population. Individuals comprising the 1996

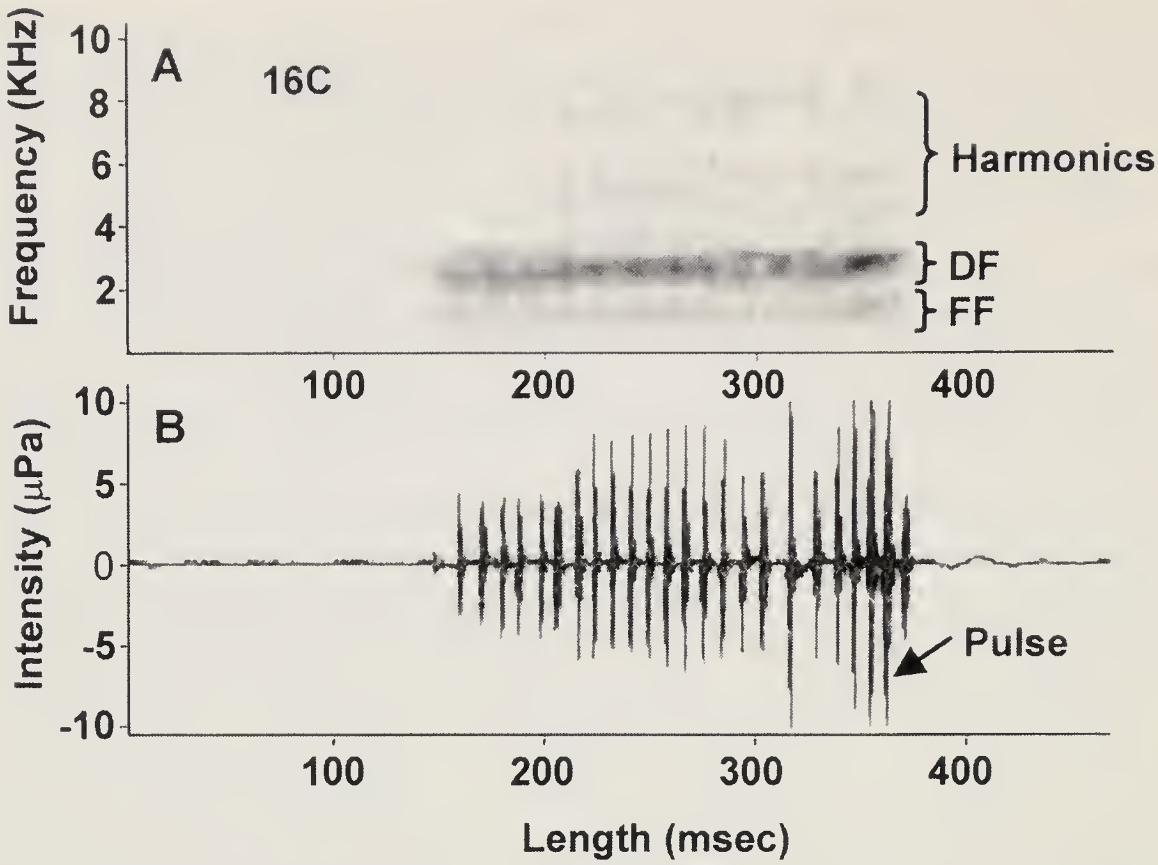

Figure 2. Graphical representation of a typical *P. brachyphona* advertisement call. (A) Spectrogram depicting the relationship between call frequency and time, DF= dominant frequency, FF= fundamental frequency. (B) Oscillogram depicting the relationship between call intensity and time.

population were uniquely toe-clipped, and none were recaptured during 1997. The pooled mean mass (± SD) was 1.36±0.06 g. Males comprising the 1996 sample (n = 7, range = 1.03-2.06 g, mean ± SD = 1.56 ± 0.14 g) were significantly larger than those comprising the 1997 sample (n=11, range = 0.9-1.8 g, mean ± SD = 1.28 ± 0.07 g) (one-tailed t =1.95, df= 16, $p < 0.04$). Body size (mass) was significantly correlated with the pitch of the male advertisement call (n = 8, r = 0.76, $p < 0.03$). More than 57% of the variation in pitch could be attributed to differences in mass among males (Fig. 4).

Male Advertisement Behavior

During 1996, male *P. brachyphona* began vocalizing on or about April 12. Three to five frogs were calling on the first night and the number increased to 6 individuals by April 21. The next night (April 22) two new males joined the chorus and no additional males were added to the chorus for the remainder of the reproductive season. Despite the fact that the potential reproductive habitat appeared to be extensive, the eight males established calling stations in close proximity to one another. The distance between calling males ranged from 5–470 cm (Mean ± SD=121.75 ± 147.82 cm) on the single night during 1996 when all eight males were participating in the breeding congress. These values were unduly influenced by male-A who had established a calling station 470 m N of his nearest competitor (male-E). If male-A is dropped from the analysis, the range of inter-male distances decreases to 5–160 cm (Mean ± SD= 72 ± 48.9 cm).

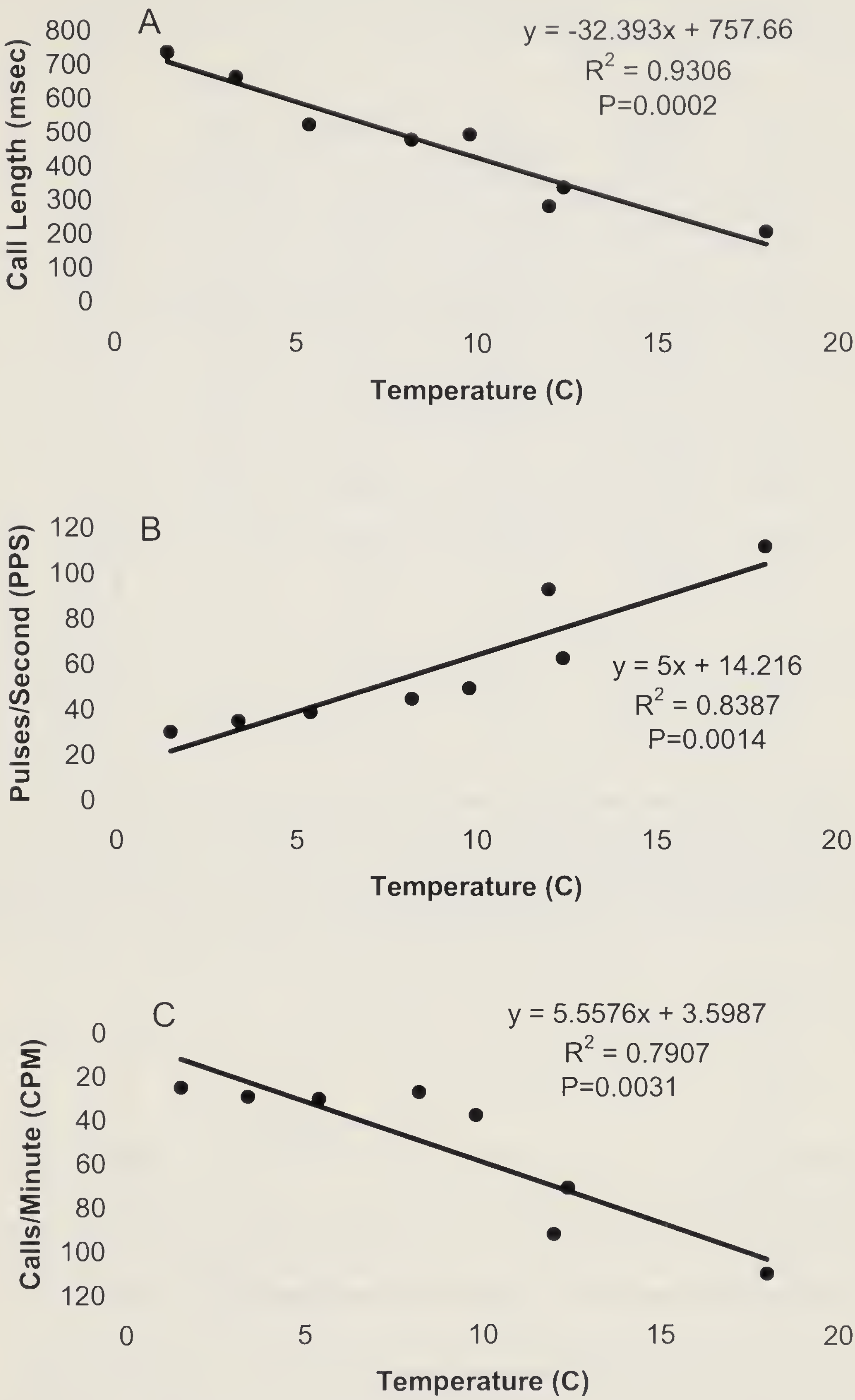

Figure 3. The influence of temperature on three temporal parameters of the male advertisement call: (A) Call Length (msec), (B) Pulses/second, (C) Calls/min.

Table 1. Call parameters of 8 *Pseudacris brachyphona* males. Mid-point of the Dominant Frequency (MPDF), Length (msec), Pulses per Second (PPS) and Calls per Minute (CPM) are Influenced by temperature and have been corrected to 11°C for comparison.

Frog	Mass (g)	Intensity (dB)	MPDF (KHz)	Pulses	Length (msec)	PPS	CPM
B-3	1.45	91.0	2.69	23.80	439.15	375.15	53.04
Z-1	1.30	82.0	2.82	27.00	322.43	242.43	82.96
D-1	1.53	81.5	2.87	21.80	391.75	337.75	61.30
E-2	1.72	82.5	2.68	25.00	464.53	394.53	42.51
Y-1	1.50	82.0	2.48	21.80	395.48	341.48	35.94
H-2	2.06	79.0	2.30	20.60	346.95	298.95	54.13
K-1	2.00	88.0	2.46	23.40	419.97	357.97	64.36
J-1	1.80	85.8	2.61	22.40	430.47	373.47	66.84
Mean	1.67	83.98	2.61	23.23	401.34	340.22	57.63
SD	0.27	3.96	0.19	2.05	47.70	49.08	14.72

During calling bouts, males typically positioned themselves along the edge of the ditch on the side farthest from the roadway. By doing so, the bank and steep slope served to project the calls outward while providing maximum cover. The microhabitat selected by calling males was clearly influenced by temperature. On nights when air

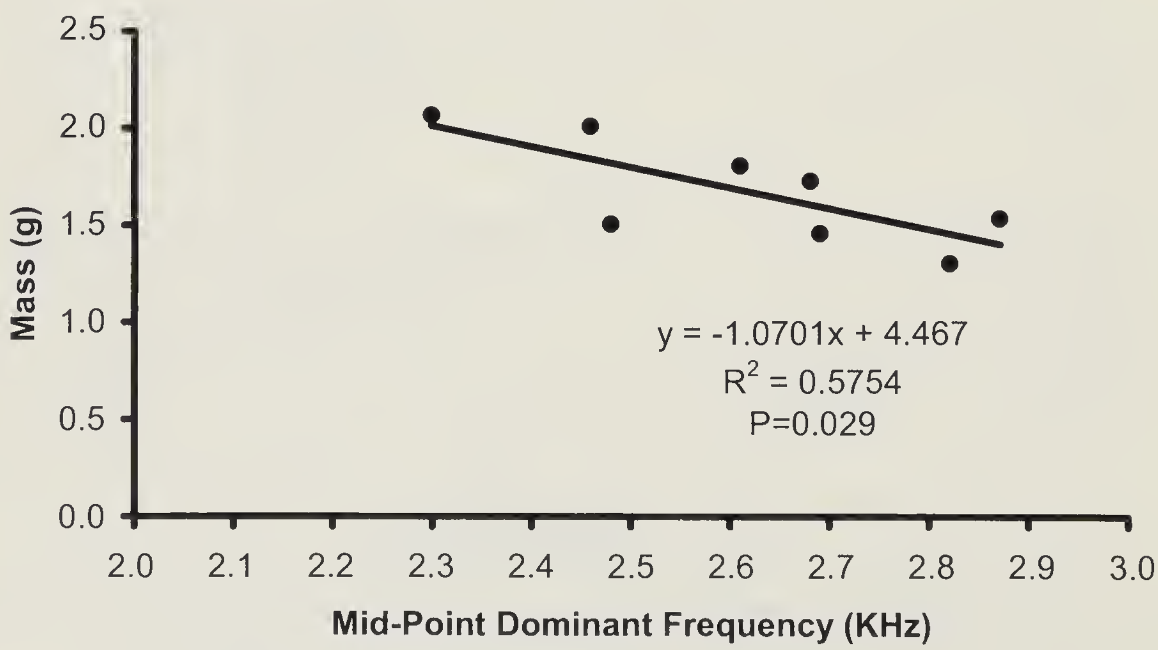

Figure 4. The relationship between body mass (g) and the dominant frequency of the male advertisement call.

temperature was lower than water temperature, males vocalized while sitting in water, whereas on warm nights they called from land. Although individual males were often observed calling in close proximity to their marker flag, the majority did not exhibit calling site fidelity, frequently establishing calling stations > 1 m apart on successive nights.

The breeding season extended over a 26-day period in 1996 (April 12-June 7). Chorus activity typically commenced at dusk as long as air temperature was above freezing. However, the intensity of calling was negatively impacted by wind and positively influenced by rain. Furthermore, the approach of automobile traffic on the adjacent roadway frequently inhibited calling activity—often for several minutes. Individual males exhibited variation in calling persistence within and between nights. Calling persistence involves the rate at which a male calls (calls per minute) as well as the proportion of a specific time period over which he calls (Forester, et al. 1989). As an example of within night variation, male-B was observed calling at a rate of 110 calls per minute (cpm) at dusk when air temperature was 12°C. By the end of the calling session, air temperature had dropped to 2°C, eliciting a concomitant decrease in calling rate (38 cpm). Furthermore, we tape-recorded male-B on four nights over a range of temperatures (5.4–18°C) and determined that his calling rate varied between sessions (28-110 cpm).

There was variation in the number of nights that individual males participated in the breeding chorus. Male-B was present during each of our visits to the site (a period of time spanning 26 days), whereas male-G was observed on a single night. The mean ($\pm$ SD) for chorus attendance by all males (n = 8) was 13.13 $\pm$ 8.15 days.

The metabolic cost of calling is outside the scope of our study. However, we recorded and weighed our most persistent caller (male-B) on three occasions during the1996 breeding season. Over a 16-day period his body mass decreased from 1.64 g to 1.45 g (−12%). This decrease is likely attributable to the energetic costs associated with persistent calling and is consistent with published reports for other hylids (Taigen and Wells 1985; Taigen, et al. 1985; Wells and Taigen 1986).

Male mating success was non-random. Male-B was one of eight males that participated in the breeding congress during 1996. Nevertheless, he is known to have amplexed three females and is suspected of amplexing a fourth.

Egg Deposition and Development

Three females were collected while in amplexus and allowed to oviposit in separate 4-L jars containing 10 cm of water taken from the ditch. The resulting clutches contained 90, 108 and 118 eggs, respectively (mean $\pm$ SD = 105.3 $\pm$ 8.2). An additional 662 eggs were oviposited at the site over the course of the 1996 breeding season. If we assume that an average clutch contains ~105 to 110 eggs, it is likely that an additional six females oviposited at the site, bring the total to nine.

Females tended to lay their eggs in small, oval clusters ranging in size from 1 X 1 cm to 3 X 3.5 cm. Sixty-seven clusters were deposited at the site or in the gallon jars during 1996. Egg clusters contained 3-50 eggs (mean $\pm$ SD = 14.6 $\pm$ 8.25) and were deposited directly on the bottom or attached to submerged vegetation at depths between 6 and 10 cm (mean $\pm$ SD = 7.35 $\pm$ 1.19 cm). In most instances the clusters produced by a single female were oviposited within two meters of one another.

However, on one occasion a female scattered her compliment of 108 eggs over 6 linear meters.

We maintained a clutch of 90 eggs in a controlled environment room on a natural photoperiod (12L:12D) at 14°C. A summary of their development is presented in Table 2. Between days 11 and 13, most of the embryos developed abnormalities and died.

On June 6, 1996 we observed several hundred late stage tadpoles at the Savage River State Forest site. The next week, a torrential rainstorm inundated Garrett County and the reproductive site was scoured by heavy runoff. The tadpoles were swept across the road and sent cascading down the adjacent mountainside, effectively destroying an entire age class of mountain chorus frogs at that locality.

Discussion

Our data document that the mountain chorus frog is a prolonged breeding species (Wells 1977; Arak 1982) and that individual males participate in a breeding congress on many nights over the course of the breeding season. Although there are no previously published reports of calling persistence by *P. brachyphona*, our data are similar to those reported for *P. crucifer* by Forester, et al. (1989).

Table 2. Early stage developmental table for *Pseudacris brachyphona* tadpoles reared on a 12:12 (L:D) photoperiod at 14°C. *Larvae developed abnormalities and died following the formation of the operculum. After Gosner (1960).

Date	Elapsed Time	Developmental Stage
05/07/96	0 days, 2 hours	early cleavage
05/08/96	1 day, 10 hours	late blastula
05/09/96	2 days, 2 hours	yolk plug
05/10/96	3 days, 0 hours	neural fold
05/11/96	3 days, 22 hours	neural tube
05/11/96	4 days, 6 hours	tail bud
05/12/96	5 days, 6 hours	muscle response
05/13/96	6 days, 2 hours	muscle movement
05/14/96	7 days, 3 hours	gill buds
05/15/96	8 days, 1 hour	heart beat
05/16/96	9 days, 3 hours	gill circulation
05/17/96	10 days, 3 hours	tail fin circulation
05/18/96	11 days, 3 hours	*opercular fold
05/20/96	13 days, 3 hours	operculum complete

Small hylids (e.g., *P. crucifer, Acris gryllus*) are reported to maintain specific intermale distances within the reproductive habitat and to defend calling stations during the breeding season (Brenowitz et al., 1984; Forester and Daniel 1986). In the current study, males were observed to vocalize from within a restricted portion of the available habitat over the course of the reproductive season, but individual males were not site specific, often moving more than a meter between consecutive calling sessions. Although we observed males vocalizing within 5 cm of a one another, characteristically calling males were >0.5 m apart and frequently appeared to reduce broadcast interference by calling antiphonally. We did not observe male-male combat, nor did we record agonistic vocalizations.

The only previously published records of the male advertisement call of *P. brachyphona* are based on the analysis of 13 calls recorded from six individuals in Georgia at 8.3°C (Thompson and Martof 1957). Their mean values for call length (0.41 sec), pulses/call (22.23 ppc) and pulses/second (55.41 pps) approximate those observed in the current study (Table 1). Thompson and Martof (1957) reported the mean dominant frequency of *P. brachyphona* as 2.29 KHz (range = 1.05-3.00 KHz). Both their mean and range are well below the values reported by us (Table 1). Although pitch is not significantly influenced by temperature, it is inversely correlated with male body size. Martof and Thompson did not report male body size for the males they recorded, but our males were relatively small in 1996 (n = 6, mean = 1.56 g), and even smaller in 1997 (n = 11, mean = 1.28 g).

Male advertisement behavior commences following snow melt, and our data corroborate the observation of Barbour and Walters (1941) that males precede females to the breeding site by as much as one week. *P. brachyphona* is adapted to reproduce in a habitat that is climatically harsh and prone to unpredictable fluctuations in temperature. In order to maximize their reproductive potential, males must be able to vocalize even when temperatures hover near freezing. Based on five recording sessions, Barbour and Walters (1941) reported that male mountain chorus frogs stopped calling once the air temperature dropped below 5°C and/or the water temperature dropped below 7.5°C. In our study however, we observed that while temporal properties of the advertisement call were significantly influenced by temperature, males continued to call when air temperatures were as low as 0°C and it was snowing. Under such conditions, vocalization typically occurred while the males were sitting in water that was several degrees C warmer. However, on one occasion we observed males calling from land when the air temperature was 1.2°C and the water temperature was 4°C.

The most significant difference between our results and those of previous investigators involves female fecundity and clutch size. Although published reports of female clutch size appear to be highly variable, all accounts are significantly larger than our mean of 105.3. Barbour and Walters (1941) dissected ten gravid females from northeastern Kentucky and found them to contain 983 to 1202 eggs (mean = 1092). Green (1938) collected four females immigrating to a West Virginia breeding site and placed them in individual jars with a male. Although one female oviposited 1,479 eggs, the other three produced clutches ranging between 318 to 406 eggs. Hoffman (1980) reported that females produce individual egg clusters containing 10–50 eggs with a total compliment not exceeding 300 eggs.

Part of the discrepancy in clutch size may be attributed to regional differences in female size, although none of the authors provided data on SUL or mass. Due to the unstable nature of our population, females may represent first year breeders. Because *P. brachyphona* is listed as threatened in Maryland, it was not possible to test this hypothesis with an intrusive procedure such as skeletochronology (Lykens and Forester 1987).

The morphometrics of *P. brachyphona* tadpoles, including a detailed description of the oral disc, have been published (Green 1938). In addition, post-metamorphic growth (Green 1964) and adult morphology have been carefully cataloged (Barbour 1957). Surprisingly, little is known about larval growth and development. Green (1938) observed that hatching occurs at 110 hours at room temperature, and Barbour and Walters (1941) reported that individuals metamorphosed in 50 days at room temperature. Although none of the tadpoles that we reared in the lab (14°C) survived to metamorphosis, we were able to collect detailed data on tadpole development through the completion of operculum formation (13 days, 3 h).

Our survey, conducted over four consecutive years (1996-1999), confirms that the mountain chorus frog populations within Maryland have declined significantly over the past half century. We were able to locate frogs at only 1 of 9 historic sites, and although that population persists to this day, it is localized and supports < 15 calling males in any given year. It is likely that other isolated populations persist in remote reaches of Allegany and Garrett counties, and their documentation and protection should be given priority.

Amphibian declines have been linked to a number of environmental and anthropomorphic factors including the introduction of exotic species (Blaustein, et al. 1994a; Freed and Neitman 1988), habitat acidification (Mathews and Larson 1980; Dunson and Wyman 1992; Sadinski and Dunson 1992), UV-B radiation (Blaustein, et al. 1994b; Grant and Licht 1993), environmental contamination by endocrine mimics such as atrazine (Hayes, et al. 2002) and habitat destruction (Petranka 1994; Hammett 1992; Reh and Seitz 1990).

The cause of the mountain chorus frog's decline in Maryland is problematic. Maryland is on the northeastern edge of the species range, and it is possible that environmental conditions are marginal for its continued success. It seems more likely, however, that the species has been negatively impacted by habitat alteration associated with commercial forestry practices, urbanization and the expansion of recreational tourism in Allegany and Garrett counties.

The single historic site that continues to support a breeding population of *P. brachyphona* is situated in the Savage River State Forest, a circumstance that should insure its protection. However, the site is composed of fewer than 20 reproductive adults, making it susceptible to inbreeding depression and genetic drift (Mayer, 1965). To make matters worse, the breeding site is adjacent to a heavily traveled county road and, as a consequence, eggs and developing larvae are susceptible to road salt runoff during the late winter and early spring. Furthermore, larvae do not metamorphose until June, and thus are potentially vulnerable to the practice of clearing ditches to promote road drainage. We recommend that the State Department of Natural Resources work with Garrett County and State Forestry officials to minimize the impact of road salt runoff and to restrict clearing roadside ditches to a time when larvae are not present.

Acknowledgements

This research was supported by a grant-in-aid to the senior author from the Wildlife and Heritage Division, Maryland Department of Natural Resources, and the sabbatical leave program of Towson University. Michael Gregory, Forest Manager of the Savage River State Forest, provided Housing and Laboratory space. James Forester provided assistance in the field. Tom Pauley and an anonymous reviewer provided constructive comments on the manuscript.

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The Status and Distribution of *Tsuga canadensis* (L.) Carr. (eastern hemlock) on the Delmarva Peninsula, and the Presence of the Hemlock Woolly Adelgid (*Adelges tsugae* Annand)

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Abstract.—Disjunct and isolated populations of *Tsuga canadensis* (eastern hemlock) are thought to represent relict stands of a once widespread forest that was present during the late Pleistocene. As the post-glacial climate warmed, these forests retreated to the north and to higher elevations in the south, creating a discontinuous distribution with peripheral populations restricted to areas with favorable conditions. The Delmarva Peninsula of the Atlantic Coastal Plain physiographic province is one region where disjunct populations of eastern hemlock survive. This study has documented 22 extant populations associated with tidal rivers and streams in 6 counties on Delmarva. The hemlock woolly adelgid (*Adelges tsugae*), an introduced insect pest native to Japan and China, has severely impacted native populations of eastern hemlock from Massachusetts to North Carolina. Hemlock woolly adelgid has been confirmed present in all but one of the native populations of eastern hemlock on Delmarva and threatens the health of these stands. Eastern hemlock on the inner Coastal Plain of the Delmarva Peninsula is an uncommon occurrence and this paper documents the current status and distribution of the species and describes overall habitat conditions. The authors hope to encourage conservation activities for these native populations and to stimulate ecological studies in order to learn more about their disjunct occurrence on Delmarva. In addition, this paper also reports on the presence of hemlock woolly adelgid in native populations of eastern hemlock on Delmarva and hopes to motivate control efforts.

Introduction

Tsuga canadensis (L.) Carr. (eastern hemlock) is endemic to eastern North America (Flora of North America 1993) and prefers cool, humid climates (Godman and Lancaster 1990). Eastern hemlock reaches its northeast extreme in New Brunswick and Nova Scotia, Canada, and is found throughout New England, New York, northern New Jersey, Pennsylvania, and eastern Ohio (Godman and Lancaster 1990). It reaches its northwest extreme in Minnesota and Wisconsin (Godman and Lancaster 1990). Within the northern portions of its range, it grows up to an elevation of 730 m above sea-level (Godman and Lancaster 1990). In the south, the species occurs through the Appalachian Mountains into northern Georgia and northeastern Alabama where it reaches its southern geographical limit (Godman and Lancaster 1990). Though eastern hemlock occurs at lower elevations in the southern Appalachians, the

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most frequent occurrences in this region are at elevations of 610 to 1520 m above sea-level (Godman and Lancaster 1990).

Disjunct populations of eastern hemlock occur in southeast Minnesota (Godman and Lancaster 1990), southwest Wisconsin (McIntosh 1950; Eickmeir et al. 1975; Parshall 2002), extreme southern Michigan and western Ohio (Godman and Lancaster 1990), southern Indiana (Daubenmire 1931; Friesner and Potzger 1931; Hotchkiss et al. 1976), western Kentucky (Godman and Lancaster 1990), northwest Alabama (Segars et al. 1951; Harper 1952), Virginia (Nemeth 1973; Harvill et al. 1992), North Carolina (Holmes 1883; Oosting and Hess 1956; Hardin and Cooper 1967), and northern Georgia (Bormann and Platt 1958).

Disjunct populations of eastern hemlock have attracted attention and research through the years (Friesner and Potzger 1931; Oosting and Hess 1956; Bormann and Platt 1958; Hardin and Cooper 1967; Nemeth 1973; Eickmeir et al. 1975; Kavanagh and Kellman 1986; Parshall 2002), and the general conclusion is that these isolated populations of eastern hemlock represent stands from a once widespread forest present during the late Pleistocene Epoch (600,000 to 12,000 years BP). Palynologic studies on the Delmarva Peninsula (Sirkin et al. 1977; Denny et al. 1979; Groot and Jordan 1999; Andres and Howard 1999) have identified *Tsuga* pollen from the late Tertiary period (Pliocene Epoch, 5.3 to 1.8 million years BP) to early Quaternary (Pleistocene Epoch, 1.8 million to 8,000 years BP). Many studies (Friesner and Potzger 1931; Oosting and Hess 1956; Bormann and Platt 1958; Hardin and Cooper 1967; Nemeth 1973; Eickmeir et al. 1975; Kavanagh and Kellman 1986; Parshall 2002) suggest that as the post-glacial climate warmed (perhaps 20,000 to 15,000 years BP), eastern hemlock retreated to the north and to higher elevations in the southern Appalachians. This retreat created a dissected and discontinuous distribution with peripheral populations being restricted to areas of favorable microclimate and edaphic conditions. The Delmarva Peninsula is one region where disjunct populations of eastern hemlock survive. Based on this study, 22 native populations of eastern hemlock are currently known extant on the Delmarva (Table 1; Figure 2).

Currently, eastern hemlock is known extant on the Coastal Plain of Long Island, New York (Greg Edinger, pers. comm.), south-central New Jersey (David Snyder, pers. comm.), the Delmarva Peninsula (Kent Co., Maryland: 18 May 2003, *McAvoy 5800* with Sophia and Ross Elliott, Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware), the Western Shore of Maryland (Dill 1962; Doug Samson, pers. comm.; Calvert Co., Maryland: 27 September, 2001, *McAvoy 5311*, Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware), and southeast Virginia (Harvill et al. 1992; Gary Fleming, pers. comm.). There are historical collections of eastern hemlock from southeast Pennsylvania that may have been from Pennsylvania's Coastal Plain province, but the species is thought to no longer occur at these locations (Ann Rhoads, pers. comm.).

The presence of eastern hemlock on the Delmarva Peninsula has been documented in the literature, but only as entries in checklists (Shreve et al. 1910; Tatnall 1946), or a flora (Brown and Brown 1972) and usually with only brief annotation. The first literature report of eastern hemlock on the Delmarva Peninsula was by Shreve et al. (1910) who reported "a single locality in the Coastal Zone (Caroline County, Watts Creek)." Tidestrom (1913) cited Shreve's report, but also made note of a new

Table 1. Distribution and population data of eastern hemlock on the Delmarva Peninsula. The presence of HWA was found in all populations, except Number 1.

Population Number	County, State	Associated River and/or Creek	Approximate Number of Trees	Trunk Diameters (in, smallest to largest)	Seedlings and Saplings
1	New Castle, Delaware	Appoquinimink River/Drawyers Creek	1	5	
2	New Castle	Appoquinimink River/Drawyers Creek	15 to 25	5 to 10	✓
3	Cecil, Maryland	Little Bohemia Creek	75 to 100	15 to 20	
4	Cecil	Sassafras River/Cox Creek	50 to 75	5 to 25	✓
5	Cecil	Sassafras River/Back Creek	50 to 75	10 to 20	✓
6	Kent, Maryland	Sassafras River/Fox Hole Landing	50 to 75	10 to 38	✓
7	Kent	Sassafras River/Jacobs Creek	75 to 100	10 to 29	✓
8	Kent	Sassafras River/Wilson Point	50 to 75	5 to 25	✓
9	Kent	Sassafras River/Swantown Creek	100 to 125	5 to 25	✓
10	Kent	Sassafras River/Turner Creek	150 to 200	10 to 25	✓
11	Kent	Sassafras River/Lloyd Creek	50 to 75	10 to 15	✓
12	Kent	Still Pond Creek	50 to 75	10 to 17	✓
13	Queen Anne's, Maryland	Wye East River	75 to 100	5 to 20	✓
14	Queen Anne's	Wye East River	5 to 10	5 to 10	
15	Talbot, Maryland	Wye East River	50 to 75	15 to 20	✓
16	Talbot	Wye East River/Pickering Creek	50 to 75	15 to 28	✓

Table 1. Continued

Population Number	County, State	Associated River and/or Creek	Approximate Number of Trees	Trunk Diameters (in, smallest to largest)	Seedlings and Saplings
17	Talbot	Tuckahoe Creek	75 to 100	5 to 15	✓
18	Caroline, Maryland	Tuckahoe Creek	30 to 40	15 to 22	
19	Caroline	Tuckahoe Creek	15 to 25	15 to 22	✓
20	Caroline	Tuckahoe Creek	25 to 50	5 to 10	✓
21	Caroline	Choptank River/Watts Creek	200 to 300	10 to 28	✓
22	Caroline	Choptank River/Mill Creek	40 to 50	5 to 10	✓

population on Tuckahoe Creek in Talbot and Caroline Counties, Maryland, which he described as "lining both banks of the river." Eastern hemlock on Delmarva was also recognized by Tatnall (1946), who pointed out, "there are eastern hemlock groves of considerable extent [in Caroline and Talbot Counties, Maryland], these appear to be native stands, probably remnants of an ancient forest." The collection record (Appendix 1) also documents its occurrence on the Peninsula, but these records have not been compiled and reviewed.

Threatening the health of eastern hemlock populations on the Delmarva Peninsula is the introduction into North America of the hemlock woolly adelgid (HWA), *Adelges tsugae* Annand (Homoptera: Adelgidae). HWA is an introduced insect pest destructive to native and ornamental hemlock trees in the eastern United States. Native to Japan and China (McClure et al. 2001), HWA was first reported in eastern North America in the 1950's at Maymont Park in Richmond, Virginia (Souto et al. 1996). The original owner of Maymont Park, James Dooley collected plants from around the world during the late 1800's until his death in 1922. Although it has not been documented, Dooley may have collected HWA infested hemlocks from Asia. From the time of its first report in North America, HWA spread slowly and was only considered an occasional pest on ornamental hemlocks. However, when HWA reached the range of native eastern hemlock populations in the mid-1980's, the rate of spread increased dramatically (Souto at al. 1996). By 1993 HWA was established from Virginia to Massachusetts. Its range currently extends from Massachusetts in the north, to eastern West Virginia in the west, and to northwestern South Carolina in the south (U.S.D.A. Forest Service; http://www.fs.fed.us/na/morgantown/fhp/hwa/hwa11201.jpg). Some of the first observations of infestations on ornamental hemlock on Delmarva were in the early 1990's (Bob Rabaglia, forest entomologist, Maryland Dept. of Ag., and Mike Valenti, Delaware Dept. of Ag., pers. comm.). The USDA Forest Service (2002) documented the presence of HWA on Delmarva from the Maryland counties of Queen Anne's (1991), Cecil (1992), Caroline (2002), Kent (2002), and Talbot (2002), and from New Castle County, Delaware (1993).

The intent of this paper is to report on the current status and distribution of eastern hemlock on the Delmarva Peninsula, describe overall habitat conditions, encourage conservation of these uncommon populations, and stimulate ecological studies in order to learn more about their disjunct occurrence on Delmarva. In addition, this paper also reports on the presence of HWA in native populations of eastern hemlock on Delmarva and hopes to motivate control efforts.

The Study Area

The Delmarva Peninsula (Figure 1) is an area lying entirely within the Atlantic Coastal Plain physiographic province of the eastern United States. The Peninsula lies south of the fall line (a term applied to the boundary between the Appalachian Piedmont province and the Atlantic Coastal Plain) of New Castle Co., Delaware and Cecil Co., Maryland, and is bordered on the east by the Delaware River, Delaware Bay and the Atlantic Ocean, and on the west by the Elk River and Chesapeake Bay. It includes the Coastal Plain province of Delaware (three counties), the Eastern Shore of Maryland (nine counties), and the Eastern Shore of Virginia (two counties). The

Figure 1. The Delmarva Peninsula with State and County boundaries indicated.

climate of the Peninsula is moderated by the Delaware Bay, Chesapeake Bay, and the Atlantic Ocean and is characterized by cool winters and warm humid summers. The mean annual temperature is 13.0°C. The coldest month of the year is January, with an average temperature of 1.5°C. The warmest month is July with an average temperature of 24° C. The average annual precipitation is 111.9 cm. March, July, and August have the highest average amounts of rainfall: 10.6 cm, 10.1 cm, and 13.2 cm, respectively. Climate data is based on a recording station in Sussex Co., Delaware near the town of Georgetown (about central Delmarva; Research and Education Center, Georgetown Delaware, College of Agriculture and Natural Resources, University of Delaware; http://www.rec.udel.edu/TopLevel/Weather.htm).

Methods

Data reported here are based primarily on field surveys done by the first author from 1995 to 2003. Data are also based on herbaria searches (Towson State University, Towson, Maryland; Delaware State University, Dover, Delaware; University of Maryland, College Park, Maryland; Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania) and review of the literature. Historical (20 years or greater) locations obtained from specimens and the literature were searched for in order to document their current status. Newly discovered populations were the result of field surveys conducted within potential habitat and from conversations with knowledgeable individuals. Potential habitat was determined through review of U.S.G.S. topographical maps (1: 24,000) to identify the appropriate landscape signature (north and east facing slopes above tidal creeks and rivers). When an historical population of eastern hemlock was relocated, or a new population discovered, the following data were collected: estimated number of individuals of eastern hemlock; the smallest and largest trunk diameter's at breast height (DBH, measured in inches); the presence/absence of eastern hemlock seedlings and saplings; aspect; and plant species composition. In addition, the following general observations were noted: position of eastern hemlock individuals on the slope (base of slope, mid-slope, crest of slope); spacing of eastern hemlock individuals (wide or close); position within the canopy (lower canopy, upper canopy) of the larger individuals of eastern hemlock; crown condition of the larger individuals of eastern hemlock (densely or sparsely foliated); the presence/absence of dead standing trunks of eastern hemlock; the degree of herbaceous plant cover in the herb-layer (low, moderate, dense); and soil drainage (dry, mesic). Criteria for defining a seedling, sapling, and tree follow Sharpe et al. (1986): seedling = individual up to 0.9 m in height; sapling = individual less than 10 cm DBH, and 0.9 to 3 m in height; tree = 10 cm or greater DBH, and 3 m or greater in height. No attempts were made to accurately measure tree heights or to age individuals through coring. The amount of area covered by a population of eastern hemlock was determined by marking its approximate location on a U.S.G.S. topographical map, then calculating the linear extent from the map. The elevations of slopes supporting eastern hemlock populations were also determined using U.S.G.S topographical maps by examining contour intervals. Soil mapping units and percent slope were determined through review of U.S.D.A. Soil Conservation Service county soil surveys (Caroline Co., MD, 1964; Cecil Co., MD, 1973; Kent Co., MD, 1982; Queen Anne's Co., MD,

1966; Talbot Co., MD, 1970; New Castle Co., DE, 1970). Voucher specimens were made from each population to document their locations, and have been deposited at the Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware. Scientific and common names for all plant species listed follows McAvoy and Bennett (2001).

To document the presence/absence of HWA in each population studied, random samples (low hanging branches with foliage) were taken from about 10 individuals in a population. However, one population contained no more than 10 individuals, in this case, about five samples were taken. Another population contained only one individual, in this case, one sample was taken. No attempt was made to determine the degree of severity (low, moderate, heavy) of HWA infestations. Samples were examined for presence/absence of HWA at the Department of Entomology at Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Results

Distribution of eastern hemlock on the Delmarva Peninsula

This report documents 22 distinct, native populations of eastern hemlock on the Delmarva Peninsula (Table 1, Figure 2). A population was defined as containing at least one individual, and is separated from another population by at least 0.5 km (0.3 mi), or a natural break in the landscape, e.g., streams, creeks, coves, and rivers. Eastern hemlock on Delmarva is distributed primarily in the northwest and west-central portions of the Peninsula. The northern most populations are in Cecil Co., Maryland (Little Bohemia Creek) and New Castle Co., Delaware (Appoquinimink River/ Drawyers Creek). The southern most populations are in Caroline Co., Maryland (Choptank River/Watts Creek and Mill Creek). The largest number of populations (Table 1) was found on the Sassafras River (8 in Cecil and Kent Co.'s, MD), Tuckahoe Creek (4 in Talbot and Caroline Co.'s, MD), and the Wye East River (4 in Queen Anne's and Talbot Co.'s, MD).

Habitat and Population Description

With few exceptions, populations of eastern hemlock on the Delmarva Peninsula were all nearly identical in physiognomy. Therefore, a habitat description that represents eastern hemlock populations on Delmarva as a whole is provided.

All populations of Eastern hemlock on Delmarva occur on slopes ranging from 6 to 12 m in height (Table 2) above tidal rivers and creeks. The average overall height of slopes supporting eastern hemlock populations on Delmarva was 8 m. Based on U.S.D.A. county soil surveys, the percent slope varied from 0 to 5%, 2 to 5%, 5 to 10%, 15 to 30%, 25 to 30%, and 15 to 40% (Table 2). The majority of populations occurred on north-facing slopes (16 populations), four populations occurred on east-facing slopes, and two populations occurred on west-facing slopes (Table 2). Individuals of eastern hemlock were usually found growing near the base of slopes to just above mid-slope. Occasionally, individuals were found growing on the crest of slopes and beyond into upland flats. Because eastern hemlock populations on Delmarva occurred on narrow linear slopes, it was difficult to determine the amount of actual land area in hectares covered by these populations. However, the largest

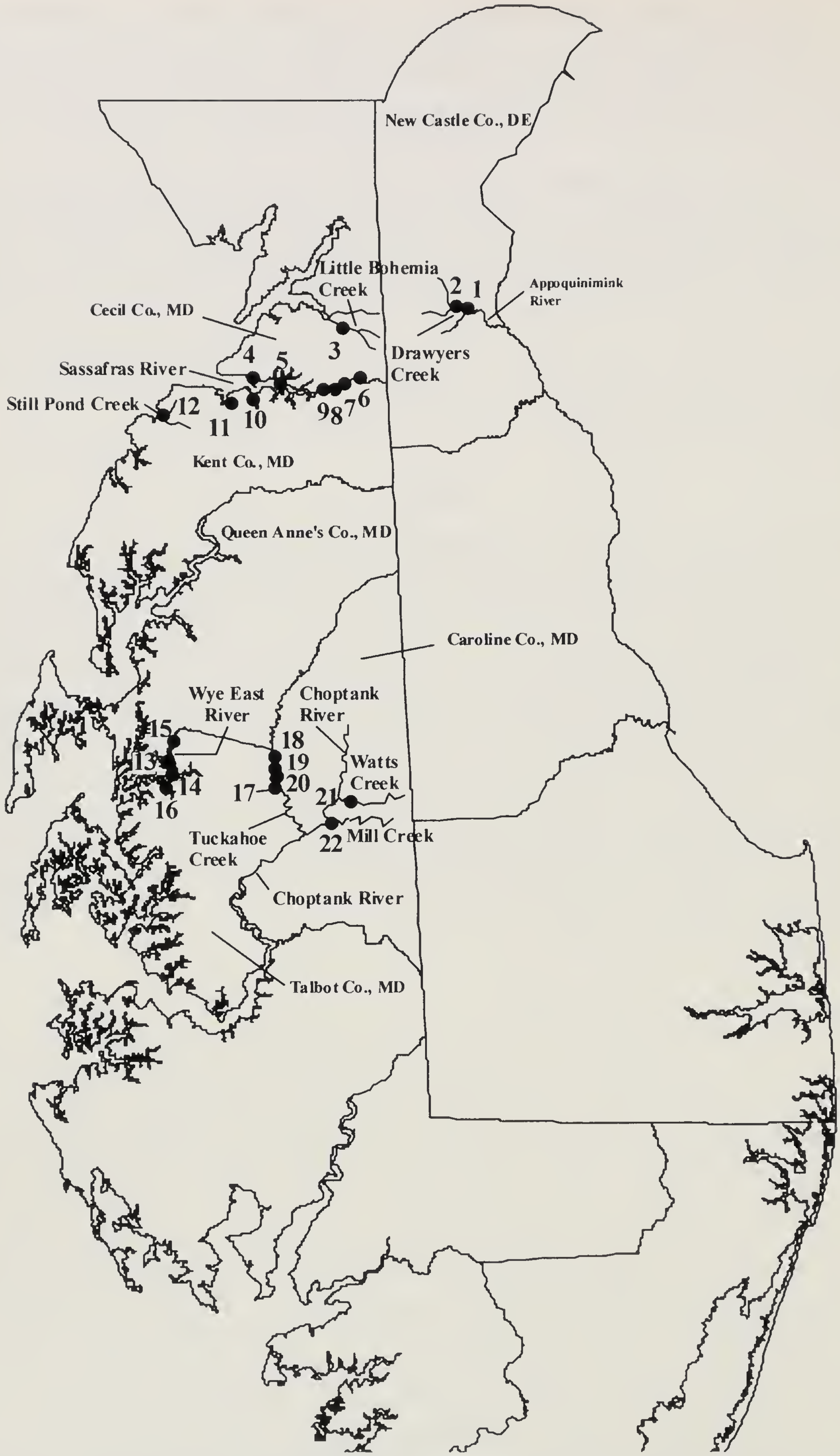

Figure 2. The geographic distribution of eastern hemlock along rivers and creeks on the Delmarva Peninsula. Numbers refer to a distinct population described in Table 1.

populations (e.g., Choptank River/Watts Creek, Caroline Co., MD; Sassafras River/Turner Creek, Kent Co., MD; Sassafras River/Swantown Creek, Kent Co., MD) did not cover more than 1 km of linear slope.

Plant species composition of eastern hemlock populations on Delmarva were fairly consistent. The canopy was usually dominated by *Quercus prinus* (chestnut oak), with *Fagus grandifolia* (American beech) as a frequent associate. Occasionally, *Acer rubrum* (red maple), *Carya alba* (mockernut hickory, synonym = *C. tomentosa*), *Ilex opaca* (American holly), *Liriodendron tulipifera* (tulip poplar), *Nyssa sylvatica* (black gum), *Quercus alba* (white oak), and *Q. velutina* (black oak) were also found in the canopy. The shrub layer was usually thin to absent, with *Kalmia latifolia* (mountain laurel) and *Vaccinium pallidum* (low-bush blueberry) being the most frequently encountered species. Species diversity in the herbaceous layer was usually low, with *Deschampsia flexuosa* (crinkled hairgrass) usually dominating. *Polypodium virginianum* (rock polypody) was a frequent associate and was often found in widespread, colonial patches. Other associates occasionally found in the herbaceous layer included: *Carex pensylvanica* (a sedge) *C. swannii* (a sedge), *C. tonsa* (a sedge), *Epigaea repens* (trailing arbutus), and *Mitchella repens* (partridge berry). The degree of plant cover in the herbaceous layer was low for all populations sampled.

Eastern hemlock on the Delmarva Peninsula never forms pure stands. The number of individuals in a population varied (Table 1), from only one (Appoquinimink River/Drawyers Creek, New Castle Co., DE) to as many as 300 (e.g., Choptank River/Watts Creek, Caroline Co., MD). Eight populations contained 50 to 75 individuals, and four contained 75 to 100. Only three populations contained more than 100. Eastern hemlock usually appears as moderately to widely spaced individuals, although occasionally, individuals can be closely spaced. Individual eastern hemlocks were usually found within the lower canopy. In nine populations, the smallest trunk diameter measured of a tree-size individual was 5 in (12.7 cm) DBH (Table 1). The average trunk diameter of the smallest trees measured in all populations was 9 in (23 cm) DBH. The largest trunk diameters measured were: 38 in (97 cm) DBH, one individual at the Sassafras River/Fox Hole Landing population (Kent Co., MD); 29 in (74 cm) DBH, one individual at the Sassafras River/Jacobs Creek population (Kent Co., MD); 28 in (71 cm) DBH, two individuals at the Wye East River/Pickering Creek (Talbot Co., MD) population, and two individuals at the Choptank River/Watts Creek (Caroline Co., MD) population (Table 1). At 12 of the 22 populations sampled, no tree greater than 20 in (51 cm) DBH was measured (Table 1). The average trunk diameter of the largest trees measured in all populations was 20 in (51 cm) DBH. In 18 populations sampled, seedling and sapling-size specimens were observed, usually in areas with low plant density and moderate sun. In all eastern hemlock populations sampled, many of the larger [(15-20 in 38-51 cm DBH)] tree-size individuals observed had very small crowns with a low number of branches. In addition, all populations (with the exception of the population containing one individual) contained at least one dead standing trunk.

Based solely on personal observations by the first author, soils of eastern hemlock slopes appeared to be mesic, but well drained. Based on species composition of the plant community (*Quercus prinus, Fagus grandifolia, Vaccinium pallidum,*

Table 2. Physical features of eastern hemlock populations on the Delmarva Peninsula: aspect, elevation, percent slope, and soil mapping unit.

Population Number	County, State	Associated River and/or Creek	Aspect	Elevation of Slope (meters)	% Slope	Soil Mapping Unit
1	New Castle, Delaware	Appoquinimink River/Drawyers Creek	N	12	15 to 30	Sassafras and Matapeake
2	New Castle	Appoquinimink River/Drawyers Creek	N	6	15 to 30	Sassafras and Matapeake
3	Cecil, Maryland	Little Bohemia Creek	N	9	15 to 40	Sassafras and Aura
4	Cecil	Sassafras River/Cox Creek	E	6	15 to 40	Sassafras and Aura
5	Cecil	Sassafras River/Back Creek	N	12	15 to 40	Sassafras and Aura
6	Kent, Maryland	Sassafras River/Fox Hole Landing	N	9	15 to 40	Sassafras and Colts Neck
7	Kent	Sassafras River/Jacobs Creek	E	12	15 to 40	Sassafras and Colts Neck
8	Kent	Sassafras River/Wilson Point	N	9	15 to 40	Sassafras and Colts Neck
9	Kent	Sassafras River/Swantown Creek	E	12	15 to 40	Sassafras and Colts Neck
10	Kent	Sassafras River/Turner Creek	N	12	15 to 40	Sassafras and Colts Neck
11	Kent	Sassafras River/Lloyd Creek	N	9	15 to 40	Sassafras and Colts Neck
12	Kent	Still Pond Creek	N	6	10 to 15	Sassafras gravelly loam
13	Queen Anne's, Maryland	Wye East River	N	6	15 to 30	Downer
14	Queen Anne's	Wye East River	N	6	2 to 5	Ingelside sandy loam

Table 2. Continued

Population Number	County, State	Associated River and/or Creek	Aspect	Elevation of Slope (meters)	% Slope	Soil Mapping Unit
15	Talbot, Maryland	Wye East River	N	6	0 to 5	Galestown loamy sand
16	Talbot	Wye East River/Pickering Creek	N	6	5 to 10	Matapeake loam
17	Talbot	Tuckahoe Creek	E	6	·	Steep Land
18	Caroline, Maryland	Tuckahoe Creek	W	6	25 to 30	Galestown loamy sand
19	Caroline	Tuckahoe Creek	W	6	25 to 30	Galestown loamy sand
20	Caroline	Tuckahoe Creek	N	6	25 to 30	Galestown loamy sand
21	Caroline	Choptank River/Watts Creek	N	6	25 to 30	Galestown loamy sand
22	Caroline	Choptank River/Mill Creek	N	6	25 to 30	Galestown loamy sand

Kalmia latifolia), and personal experience of the first author, soils of eastern hemlock slopes likely have a low pH.

HWA was confirmed present in all eastern hemlock populations sampled during this study, with the exception of one (Appoquinimink River/Drawyers Creek, New Castle Co., DE). The intensity or severity of these infestations were not measured.

Discussion

Studies of other disjunct populations of eastern hemlock (Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Borman and Platt 1958; Nemeth 1973; Hotchkiss et al. 1976; Gary Fleming, pers. comm.) in the eastern U.S. describe habitat conditions similar, or identical to what was found in eastern hemlock populations on the Delmarva Peninsula. These studies reported disjunct populations of eastern hemlock occurring on north-facing and east-facing slopes above creeks or rivers that usually covered a small land area. These studies also reported that many individuals within populations have small trunk diameters, and support sparse shrub and herb layers. Also in common with Delmarva eastern hemlock populations, these studies note that *Quercus prinus* was conspicuous in the overstory with *Fagus grandifolia* occasionally appearing, and *Kalmia latifolia* was often present in the understory. In the southern Appalachian mountains, eastern hemlock is usually restricted to north-facing and east-facing slopes, coves, or cool moist valleys (Oosting and Hess 1956; Godman and Lancaster 1990). This study of eastern hemlock populations on Delmarva, as well as others (Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Borman and Platt 1958; Nemeth 1973; Hotchkiss et al. 1976; Gary Fleming, pers. comm.), show that disjunct populations of eastern hemlock occupy similar topographic and climatic sites.

Review of U.S.D.A. Soil Conservation Service county soil surveys (Caroline Co., MD, 1964; Cecil Co., MD, 1973; Kent Co., MD, 1982; Queen Anne's Co., MD, 1966; Talbot Co., MD, 1970; New Castle Co., DE, 1970), found that descriptions of soil mapping units were not consistent between county surveys. For example, where populations of eastern hemlock were found, soil texture, soil drainage, and soil pH were not always included in the overall characterization of the mapping units. Despite inconsistencies between county soil surveys, eastern hemlock slopes on Delmarva appear to share similar soil characteristics described by Godman and Lancaster (1990). Godman and Lancaster (1990) stated that soils supporting eastern hemlock were universally characterized as moist to very moist, but with good drainage and are typically highly acid. According to the U.S.D.A. county soil surveys for Delmarva, soil drainage, when described varied. For example, terms such as "droughty," "well-drained," and "excessively drained" were used. Based on personal observations by the first author, soils of eastern hemlock slopes overall appeared to be moist, but well drained. Further review of the U.S.D.A. county soil surveys where populations of eastern hemlock occur, found that soil texture, when described also varied for mapping units. For example, sandy loam, loamy sand, gravelly loam, and silt loam were all used to characterize soil texture. Soils in Kent Co., Maryland where eastern hemlock populations have been found, are described as being "strongly acid to extremely acid" (U.S.D.A Soil Conservation Service, Kent Co., MD, 1982). The presence of acid-

loving plants, such as *Quercus prinus, Fagus grandifolia, Vaccinium pallidum,* and *Kalmia latifolia* found growing within eastern hemlock populations on Delmarva, indicate that soils overall likely have a low pH.

The association of eastern hemlock populations on Delmarva with rivers and creeks help to explain in part why these disjunct stands have persisted on the Peninsula. Studies by Segars et al. (1951) and Oosting and Hess (1956), suggested that the occurrence and persistence of disjunct populations of eastern hemlock may be partially attributed to the relatively high humidity of the habitats. Oosting and Hess (1956) point out that most populations were in close proximity to a permanent stream with local humidity probably higher than that of the surrounding area. As mentioned above, individuals of eastern hemlock were usually found near the base of the slope, to just above mid-slope, but occasionally on the crest of slopes and beyond. Oosting and Hess (1956) found on the "bluffs" where eastern hemlock occurred exclusively, that temperature and evaporation were lower and available soil moisture greater than on the crest of the bluff where eastern hemlock was absent. In addition, Oosting and Hess (1956) suggested that an excess of evaporation over precipitation may limit the range of eastern hemlock southward. Perhaps this is one factor why eastern hemlock is currently known only from the northern Atlantic Coastal Plain (Long Island, New York to southeast Virginia) and not further south.

Native populations of eastern hemlock on the Delmarva Peninsula are uncommon. Data presented in this paper, as well as the literature and the early collection record (Appendix 1) supports this status. Shreve et al. (1910) reported that eastern hemlock is known from "a single locality in the Coastal Zone (Caroline County, Watts Creek)." Tidestrom (1913) pointed out that "so far as I know we have only one published record of this tree from the coastal plain," which is in reference to Shreve's report, but in the same paper discusses a new population he visited in 1912. Fowler (1957) states that "hemlock is rare or absent from the coastal plain in Maryland." Brown and Brown (1972) described eastern hemlock in Maryland as "mostly in the Mountain Zone, a few small stands occurred on the Eastern Shore and one along Hellen Creek in Calvert County [Western Shore]." The collection record (Appendix 1) revealed only seven historical localities of eastern hemlock on Delmarva. All seven sites were relocated by the first author, and 15 sites were newly discovered and vouchered. Although eastern hemlock certainly appears to be an uncommon species on Delmarva at this time, it is likely that additional populations will be discovered in the future. A review of U.S.G.S. topographical maps indicates more potential habitat that needs to be explored.

It should be noted that Tatnall (1946) thought the occurrence of eastern hemlock on Drawyers Creek (Appoquinimink River, New Castle Co., DE) "may have sprung from planted trees in the grounds of near-by Drawyers Church." This population is nearly identical to the native populations in the Maryland counties of Delmarva. A new population was also discovered during this study on Drawyers Creek that is 0.8 km (0.5 mi) to the east. In addition, Drawyers Church was constructed in 1861 and it is likely impossible to determine if the eastern hemlock found on the grounds of the church were ever actually planted. Therefore, the first author believes the Appoquinimink River/Drawyers Creek (New Castle Co., DE) populations are native.

The Sassafras River appears to be the strong-hold for eastern hemlock on the Delmarva Peninsula. The largest number (8) of populations of eastern hemlock found during this study were on the Sassafras River in Cecil and Kent Co., Maryland (Table 1, Figure 2). Though discontinuous, these populations extended from the west on Lloyd Creek, to the east at Fox Hole Landing for a distance of about 18 km (12 mi). Three populations (Turner Creek, Swantown Creek, and Jacobs Creek) supported 100 or more individuals, and five populations supported up to 75 individuals. It is estimated that the Sassafras River supports at least 800 individuals of eastern hemlock, more than any other river system sampled during this study. In addition, the largest diameter trees measured were from Sassafras River populations [38 in DBH (98 cm) Fox Hole Landing, 29 in DBH (73 cm) Jacobs Creek]. The average diameter of the largest trees from all populations sampled on the Sassafras River is 25 in (62 cm) DBH, which is greater than the overall average of 20 in (50 cm) DBH from all populations sampled during this study. Additionally, all populations on the Sassafras River contained seedlings and saplings.

With the exception of a few populations (e.g., Choptank River/Watts Creek, Caroline Co., MD; Sassafras River/Turner Creek, Kent Co., MD; Sassafras River/Swantown Creek, Kent Co., MD), the overall vigor of eastern hemlock on Delmarva appears to be poor, perhaps due to their disjunct, peripheral occurrence. Central populations of a species distribution experience the most favorable environmental conditions, and these favorable conditions decrease with an increase in distance from the center (Kavanagh and Kellman 1986; Lesica and Allendorf 1995). As a result, populations disjunct from the center of the species range are likely to occur in ecologically marginal or stressful conditions, and are typically less vigorous than central populations (Kavanagh and Kellman 1986; Lesica and Allendorf 1995). Although the following characteristics do not necessarily indicate a low degree of vigor, all populations covered less than one linear kilometer (0.6 mi) of slope; only 3 populations had more than 100 estimated individuals, and 8 had no more than 75; most crowns were narrow with a low number of branches supporting foliage; and all but one population had at least one dead standing trunk. Early studies (Holmes 1883; Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Nemeth 1973; Gary Fleming, pers. comm.) of disjunct populations of eastern hemlock also describe conditions of stress and low vigor. For example, descriptions such as: "do not present a healthy vigorous appearance and quite certain to be short lived (Holmes 1883);" "small in size," and "crowded out" (Friesner and Potzger 1931); "few trees," and "slowly dying out" (Oosting and Hess 1956) have been used.

The infestation of HWA in all but one population of eastern hemlock on Delmarva could also be contributing to the overall appearance of low vigor. For example, individuals with narrow crowns and sparse foliage, and the presence of dead standing trunks could be the result of destructive feeding by HWA. Although, the early studies of disjunct populations of eastern hemlock previously mentioned (Holmes 1883; Daubenmire 1931; Friesner and Potzger 1931; Oosting and Hess 1956; Nemeth 1973; Gary Fleming, pers. comm.), report conditions of stress and low vigor without the presence of HWA. Whether the expression of low vigor that currently characterizes most eastern hemlock populations on Delmarva is the result of their disjunct periph-

eral occurrence, or the infestation of HWA, or both, the presence of HWA is a stress that these populations may not be able to withstand.

On a positive note, reproduction of eastern hemlock on Delmarva is occurring, of the 22 populations sampled, seedlings and saplings were observed in 18 (Table 1).

Hemlock Woolly Adelgid and Control Efforts

HWA was first reported on Delmarva in the early 1990's on ornamental hemlock (Bob Rabaglia, forest entomologist, Maryland Dept. of Ag., and Mike Valenti, Delaware Dept. of Ag., pers. comm.), and by 2002, six counties had become infested (USDA Forest Service 2002): Queen Anne's, MD (1991); Cecil, MD (1992); New Castle County, DE (1993); Caroline, MD (2002); Kent, MD (2002); and Talbot (2002). The earliest HWA infestation reported by the USDA Forest Service (2002) occurred in Queen Anne's County in 1991. This county is centrally located on Delmarva and may have been the source of the infestation for the surrounding counties.

The eastern hemlock population not infested with HWA (Appoquinimink River/Drawyers Creek, New Castle Co., DE), consisted of a single, apparently healthy individual [5 in (12.5 cm) DBH, estimated to be about 6 m (20 ft) tall]. This individual occurred 0.8 km to the east of another much larger population infested with HWA. Quite often, lone individuals of eastern hemlock remain uninfested for longer periods of time than larger populations of eastern hemlock that are infested (personal observation, T. McAvoy).

HWA spreads at an estimated rate of 20 – 30 km (12-19 km) each year (McClure et al. 2001) and wind, birds, deer, and humans help its spread (McClure 1990). HWA feeds at the base of needles and penetrates into the parenchyma cells of the xylem (McClure et al. 2001). In time, needle loss results, as well as an inability to develop new apical buds (McClure 1990; McClure et al. 2001). Little if any new growth is produced on infested branches (McClure et al. 2001). Dieback of major limbs can occur within two years and progresses from the bottom of the tree upward (McClure et al. 2001). Heavy infestations have killed trees in four years, but some trees have survived infestations for more than 10 years with only a sparse amount of foliage at the very top of the crown (McClure et al. 2001). In Delmarva eastern hemlock populations, HWA appeared as small, white cottony balls at the base of needles. Needle loss, and dead or dying limbs were observed in individuals that were infested with HWA.

Some success in combating HWA has been found by using biological control agents. In North America, there are only a few native insect species that prey on HWA and their predation is not enough to make a significant impact on population densities (McClure et al. 2001; Wallace and Hain 2000). Limited and controlled releases of a predatory beetle, *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) native to Japan, have shown a 47 – 87% reduction in HWA densities in monitored populations (McClure 1999; McClure et al. 2001). Currently, the second author is involved in a project at Mountain Lake, Virginia to control HWA using soil and stem injections of imidacloprid. This is a systemic insecticide that has proven effective against HWA (Silcox 2002). Preliminary results have demonstrated control of HWA on these eastern hemlocks with no harmful effects to non-target organisms. These insecticide applications are intended to slow the harmful effects of HWA until introduced biological control agents (*Pseudoscymnus tsugae*) become abundant enough to control HWA.

Pseudoscymnus tsugae was released in this area in 2000 and a second biological control agent *Laricobius nigrinus* (Zilahi-Balogh et al. 2002) will soon be released. Efforts to control HWA on the Delmarva Peninsula, possibly with imidacloprid applications and release of biological control agents should be initiated in the very near future.

Conclusion

It is hoped that this paper will spark the interest of students and researchers to study populations of eastern hemlock on the Delmarva Peninsula in order to better understand their existence here and to examine ecological differences and relationships that may exist between populations. For example, why does the Sassafras River support the highest number of populations, the highest number of individuals, and the largest diameter trees than any other system sampled? Another example of research needs concerns local land-use history. How has land clearing for agriculture and development impacted native populations of eastern hemlock on Delmarva? Has eastern hemlock on Delmarva ever been an attractive species for timber sales? Research concerning land-use history could add to our overall understanding of the species current status, and perhaps historical status on Delmarva. In addition, soil studies should also be initiated. A better understanding of the soil types associated with each population may provide more insight into the species distribution and frequency of occurrence on Delmarva. Also, comparative studies between disjunct eastern Coastal Plain populations, and populations from within the core of the species range should also be considered; results may find physiological and morphological differences. A comparison of two geographically distinct populations in Wisconsin (Eickmeir et al. 1975) found physiological and morphological differences in seedlings between a disjunct population in the southwest portion of the state, and one from a central population from the northeast portion of the state. Findings indicate that eastern hemlock in Wisconsin exhibits two physiological races correlated with environmental conditions. Seedlings from the southwest population of the state are better adapted to the warmer, drier conditions found in that region and seedlings from the northeast population are better adapted to the cooler, wetter conditions found in that part of the state (Eickmeir et al. 1975). Godman and Lancaster (1990) report no studies regarding the genetics of eastern hemlock in North America. Examining and comparing the potential genetic variability of disjunct Coastal Plain populations with populations from the core of the species range may prove interesting.

Although evidence of reproduction of eastern hemlock populations on Delmarva was observed, there is an apparent lack of overall vigor of these populations, and the presence of HWA in 21 of 22 populations sampled, suggests a trend toward extirpation, therefore, this paper hopes to motivate conservation efforts to protect and enhance eastern hemlock populations on Delmarva and to control HWA. Species conservation depends upon protecting the genetic variability present throughout the range of the species, thus these uncommon disjunct inner Coastal Plain populations should have high value for conservation.

Acknowledgments

The authors are extremely grateful to the following individuals for their valuable contributions and time in helping with various aspects of this paper: Karen Bennett, Peter Bowman, Lynn Davidson, Janet Ebert, Greg Edinger, Gary Fleming, Jason Harrison, Frank Hirst, Jack Holt, Kevin Kalasz, Olin Allen, Patricia McAvoy, Rob Naczi, Bob Rabaglia, Ann Rhoads, Doug Samson, David Snyder, Mike Valenti, and Terry Van Horn. Special thanks go to Sophia and Ross Elliott for their help in collecting field data, and to Susan Borst for all her efforts in tracking-down and delivering hard to find literature sources.

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Appendix 1

The historical and modern day collection record of eastern hemlock on the Delmarva Peninsula (DOV = Claude E. Phillips Herbarium, Delaware State University, Dover, Delaware; PH = Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania)

Delaware: New Castle Co., Old Drawyers Church, wooded slope overlooking creek, 4 July 1929, *Tatnall 420* (DOV); N facing slope below Old Drawyers Church, Drawyers Creek/Appoquinimink River, 15 June 1999, *McAvoy 4395* (DOV); N facing slope above Drawyers Creek, 0.5mi E of Old Drawyers Church, 26 September 2001, *McAvoy 5310* (DOV).

Maryland: Caroline Co., Tuckahoe Creek, 2.5mi. S of Hillsboro, 13 October 1935, *Wherry s.n.* (PH); 2.5mi. S of Hillsboro, W bank of Tuckahoe River, 22 August 1936, *Tatnall 3113* (DOV); 2.5mi. S of Hillsboro, below Wayman Wharf, E bank of Tuckahoe Creek, 16 October 1937, *Tatnall 3630* (DOV); N facing slope on Tuckahoe Creek, S of Stony Point, 11 September 1998, *McAvoy 4084* (DOV); N facing slope on Tuckahoe Creek, 2mi. south of Hillsboro, 24 September 2002, *McAvoy 5688* (DOV); W facing slope on Tuckahoe Creek, 1mi. S of Stony Point, 24 September 2002, *McAvoy 5690* (DOV); W facing slope and woodland flats near Stony Point parking area and boat launch, south of Hillsboro, 24 September 2002, *McAvoy* 5708 (DOV); N facing slope on Watts Creek/Choptank River, S of Denton, 23 August 2001, *McAvoy 5249* (DOV); N facing slope on Mill Creek/Choptank River, S of Williston, 23 August 2001, *McAvoy 5251* (DOV); Cecil Co., Little Bohemia Creek, facing N, 3mi. northwest of Warwick, 31 June 1942, *Schmid s.n.* (PH); N facing slope, Little Bohemia Creek, 7 August 1995, *McAvoy 1196* (DOV); N facing slope, Knight Island Peninsula, Back Creek/Sassafras River, SW of Cecilton, 20 May 1997, *McAvoy 2217* (DOV); E

facing slope on Cox Creek/Sassafras River, W of Cecilton, 22 August 2001, *McAvoy 5245* (DOV); Kent Co., N facing slope, Lloyd Creek/Sassafras River, E of Betterton, 30 October 1998, *McAvoy 4222* (DOV); N facing slopes above Turner Creek/Sassafras River, W of Galena, 13 October 2000, *McAvoy 5024* (DOV); N facing slope above Turner Creek/Sassafras River, east of Betterton, 23 September 2002, *McAvoy 5673, 5674* (DOV); N facing slope on Codjus Cove/Still Pond Creek, SW of Betterton, 11 July 2001, *McAvoy 5159*, (DOV); N facing slope on Sassafras River/Fox Hole Landing, E of Fox Hole Landing, NE of Galena, 6 April 2003, *McAvoy 5716* with Jack Holt, (DOV); E facing slope on Sassafrass River/Jacobs Creek, NE of Galena, 3 May 2003, *McAvoy 5748* with Sophia and Ross Elliott, (DOV); N facing slope on Sassafrass River/Wilson Point, NE of Galena, 18 May 2003, *McAvoy 5799* with Sophia and Ross Elliott, (DOV); E facing slope on Sassafras River/Swantown Creek, NE of Galena, 18 May 2003, *McAvoy 5800* with Sophia and Ross Elliott, (DOV); Talbot Co., high banks along Tuckahoe Creek, 3mi. ENE of Cordova, 26 December 1936, *Earle 1315* (PH); E facing slope on Tuckahoe Creek, 3mi. S of Hillsboro, 24 September 2002, *McAvoy 5689* (DOV); East Wye River, 2.5mi SW of Wye Mills, 5 July 1937, *Earle 1550* (PH); N facing slope, Wye East River, N of Wye Landing Lane, 30 October 1998, *McAvoy 4209* (DOV); N facing slope on Pickering Creek/Wye East River, 5 November 2002, *McAvoy 5704* (DOV); Queen Anne's Co., N facing slope on Wye East River, SW of Wye Mills, 30 October 1998, *McAvoy 4210* (DOV); N facing slope on Wye East River, S of Wye Landing, 5 November 2002, *McAvoy 5703* (DOV)

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ISSN 0096-4158

THE MARYLAND NATURALIST

Volume 46, Number 2 Winter 2003

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FOUNDED IN 1929

A BIANNUAL PUBLICATION OF THE NATURAL HISTORY SOCIETY OF MARYLAND

The Maryland Naturalist

A Biannual Publication of the Natural History Society of Maryland

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Published by the Natural History Society of Maryland, Inc.
2643 North Charles Street
Baltimore, MD 21218, USA
410-235-6116
www.marylandnature.org

Printed by Cadmus Journal Services
Linthicum, MD 21090, USA

Occurrence of the Least Bittern in the Nanticoke Watershed, Delaware

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The Least Bittern (*Ixobrychus exilis*) inhabits tidal and non-tidal freshwater and brackish marshes, nesting in areas with dense emergent vegetation including scrub-shrub wetlands. In Delaware, the species is known from along the Delaware Bayshore marshes and impoundments from about Delaware City south to the marshes of Prime Hook National Wildlife Refuge (Hess et al. 2000). Hess et al. (2000) consider the species uncommon to fairly common in appropriate habitat within coastal marshes. Statewide, the Delaware Natural Heritage Program consider the species imperiled and of high conservation concern (natural heritage state rank of S1). The Maryland Natural Heritage Program lists the species as imperiled (natural heritage state rank of S2). We report here an observation of a Delaware Least Bittern found in a freshwater tidal marsh within the Chesapeake Bay watershed. This report is substantially west and south of previous Delaware reports.

On 30 June 2003, while kayaking on Broad Creek in the Nanticoke Wildlife Management Area, Sussex County, Delaware, we encountered a calling Least Bittern. The bird was calling continuously and emphatically at mid-day (1240 – 1300) from within a freshwater tidal emergent marsh along Broad Creek 0.75 km northeast of Phillips Landing. Calls were from an area of dense vegetation primarily comprised of *Nuphar advena, Acorus calamus* and *Typha latifolia*. Although we did not see the bird, we were able to obtain an excellent recording of the bird's calls. Later, the calls were confirmed as those of Least Bittern by creating spectograms and comparing them with those displayed in Gibbs et al. (1992). Thus, the calls represented the "cooing" form of the species' call repertoire as described in Gibbs et al. (1992). The above date is well within the expected breeding dates of this species (see Robbins and Blom 1996); thus, we consider this a territorial occurrence. In June 1996, a property owner in Sussex County described to CMH the vocalization of an unknown bird she had heard calling from the scrub-shrub emergent wetlands along Wright Creek in the Nanticoke Watershed just east of the Maryland-Delaware State Line. Based on the description, CMH thought the calls likely to be that of a Least Bittern but breeding-season occurrences of the species had not previously been documented from that area in Delaware.

The Least Bittern was not found within the Nanticoke Watershed during the Delaware Breeding Bird Atlas project (Hess et al. 2000). Apparently, Hess et al. (2000) did not expect the species would be found here; the species' account in *The Birds of Delaware* focuses only on the coastal wetlands on the east side of the state. Robbins and Blom (1996) show a concentrated area of "possible" breeding occurrences from the Maryland Breeding Bird Atlas project along the Nanticoke River and its tributaries a fair distance southwest of the Maryland-Delaware state line and close to the

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Chesapeake Bay. Thus, the confirmation of this species calling during the breeding season this far inland from the Chesapeake Bay is significant, especially considering the lack of records from this watershed in Delaware.

The Delaware portion of the Nanticoke River and its extensive network of tributaries maintain emergent, scrub-shrub, freshwater marshes from the Maryland state line north through to about Middleford, Sussex County. However, extensive and dense stands of mixed emergent and scrub-shrub vegetation become less common northward. Biologists should consider the existing areas of dense emergent wetlands in the Nanticoke watershed potential breeding habitat for Least Bittern. The increase in boating traffic in this area, including that of jet skis, should be of concern to wildlife managers and environmental review specialists; bitterns place nests near open water usually between 15 and 76 cm above the water surface (Gibbs et al. 1992). Un-natural wave action from motorized water vehicles may threaten lower nests, especially considering that watercraft traffic likely increases as the nesting season progresses.

Emergent marshes in the Nanticoke watershed in Maryland and Delaware should be surveyed for Least Bitterns. Surveys of freshwater marshes of the breeding occurrences of Least Bittern should be delineated and monitored in order to better understand this species' habitat requirements, its distribution, and its abundance throughout this portion of the peninsula.

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Discovery of the Jefferson Salamander, *Ambystoma jeffersonianum* (Green), east of the Blue Ridge Mountains, in Frederick and Montgomery County, Maryland

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Introduction

The Jefferson Salamander *Ambystoma jeffersonianum* was named after the type locality (and indirectly, President Thomas Jefferson) at Jefferson College, Pennsylvania. Several characteristics distinguish it from other ambystomatid species. It is relatively long and gracile, with slender toes and a tail that is laterally compressed and tapers to a point. The color pattern varies with age with older individuals exhibiting a uniform brownish black color, while younger individuals are typically grayish black with lighter color gray on the sides and venter. The dorsum and sides are covered with pale blue flecks that tend to be both larger and more numerous on the sides than on the back. The spots become less evident with age and may be entirely absent in older individuals (Hulse et al. 2001). Dyrkacz (1981) reported that albino individuals have been found in Maryland and Ohio.

Jefferson salamanders often breed syntopically (at the same sites) with other ambystomadid species (Thompson and Gates 1982). However, Jefferson salamander egg masses can be differentiated from other species because they are usually cylindrical in shape and are relatively small (about 5.0 cm X about 2.5 cm; Bishop 1941; Petranka 1998). Preferred breeding sites are fishless, ephemeral and permanent ponds with abundant vegetation (Thompson et al. 1980; Thompson and Gates 1982). Spawning typically takes place during late winter or early spring. Spawning begins earliest in the southern part of its range and later to the north. In Kentucky, adults were found migrating to breeding ponds as early as October and November (Douglas and Monroe 1981), and Smith (1983) found eggs in Kentucky during January. Adults were found in a breeding pond during late April in Ontario (Weller and Sprules 1976). In Maryland, breeding occurs between mid-February and the end of the first week of March (DCF, personal observation). This corresponds with published reports of the breeding cycle of *A. jeffersonianum* in West Virginia (Wilson and Friddle 1950).

Adults and juveniles are rarely seen outside the breeding period (Petranka 1998) and presumably spend most of their time underground in rodent burrows and similar retreats. However, researchers have reported finding adults and juveniles to be abundant near the surface, under logs and bark during the fall, well outside the breeding season (Bishop 1941; Judd 1957; this report).

The geographic distribution of the Jefferson salamander ranges from southern New England southwestward to Indiana, Kentucky, West Virginia, and Virginia

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(Petranka 1998). Harris (1975) reported its occurrence at seven localities restricted to Allegheny, Washington, and western Frederick counties, Maryland (Fig. 1). Thompson (1984) added 55 localities based on surveys of breeding ponds in Garrett, Allegheny, Washington, and Frederick counties and reported the distribution to be restricted to within the Potomac River drainage from eastern Garrett County to the Blue Ridge Mountains.

New Discoveries

A single male Jefferson salamander was discovered beneath a rotten log adjacent to a small depression pond located in a portion of the Chesapeake and Ohio Canal National Historic Park, located in eastern Frederick County, Maryland during October 2000. An additional six adults (two females and four males) and more than 30 egg masses were observed in a series of depression ponds near this site during February 2001. The ponds were located in an open grassland habitat, NW of the Monocacy River that separates Frederick and Montgomery counties. Smaller ponds in the complex were lined with mature hardwood trees while the larger pond is best described as a flooded forest positioned between the grassland and the Monocacy River. After photographing one male, each of the adults was released at the point of capture.

Two specimens of Jefferson salamander were independently discovered in Montgomery County, Maryland, approximately nine kilometers southeast of Poolesville. During October 2001, a single adult specimen was collected in McKee Beshers

Figure 1. Distribution of Jefferson salamander in Maryland including historic records (Harris 1975;Thompson 1984) and recent records east of the Blue Ridge Mountains.

Wildlife Management Area. The specimen was found under a board in a moist area east of Sycamore Landing Road and was released at the point of capture. During September 2003, another adult specimen was collected from under a piece of tree bark on the ground, adjacent to the Chesapeake and Ohio Canal between the McKee Beshers Wildlife Management Area and the Seneca Creek State Park. Photographs of this specimen were taken immediately and are kept as photographic vouchers in the Maryland Department of Natural Resources, Maryland Biological Stream Survey photo documentation library (Fig. 2). A marbled salamander (*Ambystoma opacum*) was found with both of the specimens found in Montgomery County. A spotted salamander (*Ambystoma maculatum*) and an eastern red-spotted newt (*Notophthalmus viridescens viridescens*) were also found at the Chesapeake and Ohio Canal site. The presence of four pond-breeding salamanders at this site indicates that this part of the Chesapeake and Ohio Canal, which consists of a series of large ephemeral ponds with an abundance of vegetation and woody debris, provides excellent breeding habitat. Refuge from predation may also contribute to high salamander richness, as permanently dry areas restrict predatory fishes from invading from other portions of the canal (SAS, personal observation).

The area surrounding both of these sites primarily consists of a large mature forest within three contiguous parcels of protected, public land including McKee Beshers Wildlife Management Area (809.4 ha), Seneca Creek State Park (2549.5 ha), and a portion of the Chesapeake and Ohio Canal National Historical Park (0.20 ha; Fig. 3). This area has an abundance of downed trees, rotting logs, and other substrates that provide retreats for adult and juvenile pond-breeding salamanders outside the breeding period.

Figure 2. Photograph of the Jefferson salamander specimen collected during September 2003 in the Chesapeake and Ohio Canal National Historical Park.

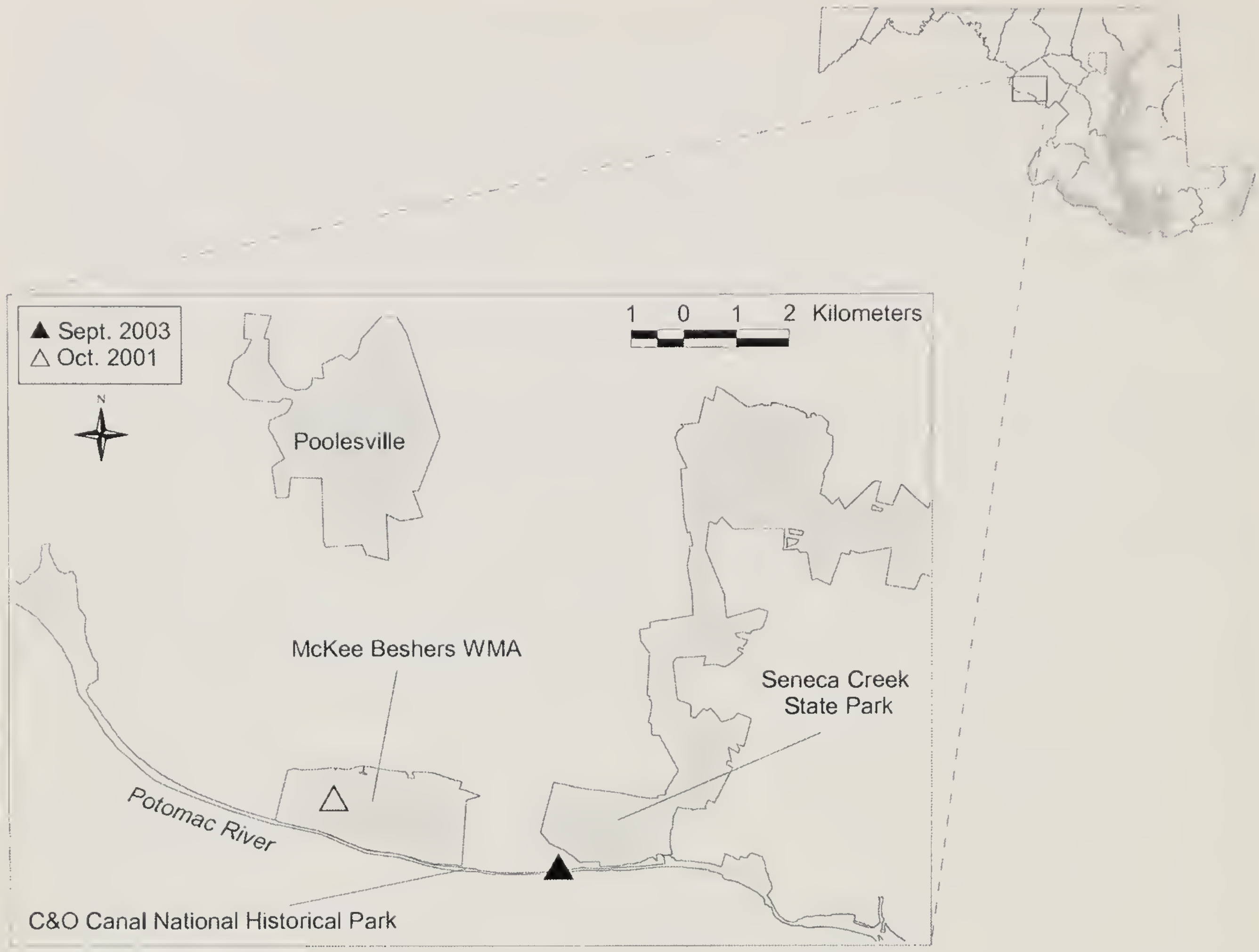

Figure 3. Location of recent collections (September 2003 and October 2001) of Jefferson salamander in the Chesapeake and Ohio Canal National Historical Park and McKee Beshers Wildlife Management Area in southern Montgomery County, Maryland.

These records indicate that the distribution of the Jefferson salamander includes eastern Frederick County as well as Montgomery County east of the Catoctin Mountains and may represent an eastward expansion of this species across the Blue Ridge divide via the Chesapeake and Ohio canal. The canal parallels the Potomac River and has been recognized as a likely corridor through which several Coastal Plain fish species have expanded their range westward across the Fall Line into the Piedmont province of the Potomac River in Montgomery County (Starnes 2002). Several anurans, including the Northern Cricket Frog (*Acris c. crepitans*), the Upland Chorus Frog (*Pseudacris feriarum*) and Fowler's Toad (*Bufo fowleri*), have also followed the Potomac River Valley from the Atlantic Coastal Plain westward into the Valley and Ridge Physiographic Province of western Maryland (Harris 1975; Conant and Collins 1998; DCF, personal observation). It is reasonable to assume that the C&O Canal may continue to serve as a dispersal corridor for other aquatic or semi-aquatic amphibian taxa across regional barriers such as the Blue Ridge divide.

Summary

The Jefferson salamander is currently on Maryland's Watch List indicating that it is an important species that is considered to be rare or uncommon and may be

susceptible to large-scale disturbances (MDDNR 2001). Adults are rarely seen except during the spring breeding season and possibly during the fall. The specimens collected in 2000 represent the first known occurrences of this species in southern Frederick County east of the Blue Ridge Mountains. The specimens collected in 2001 and 2003 are the first records known for Montgomery County and show that the Jefferson salamander geographic distribution in Maryland extends at least 48 km southeast of any previously documented occurrences. Based on this relatively large distance between newly discovered populations and previously documented records, surveys of potential breeding ponds in southern Frederick County and western Montgomery County, especially within and around the Chesapeake and Ohio Canal are warranted. Such surveys could be used to generate a more complete description of Jefferson salamander distribution east of the Blue Ridge Mountains.

Acknowledgements

We thank the National Park Service for funding Maryland Biological Stream Survey sampling in the Chesapeake and Ohio Canal National Historical Park. We also thank Chris Millard, Ron Klauda, Paul Kazyak, Dan Boward, Martin Hurd, Anthony Prochaska, and Ann Schenk for their assistance and review of this manuscript.

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The Vascular Flora of Minnies Island, Montgomery County, Maryland

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Abstract.—A survey of the vascular flora of Minnies Island, a small island in the Potomac River, was conducted from March to October, 2002. Minnies Island is approximately 3 km northwest of the District of Columbia, adjacent to the Chesapeake and Ohio Canal National Historical Park in the Potomac River Gorge. The study site comprised 3 ha of mostly broadleaf deciduous forest growing on alluvial soils and rock outcrops with a mixture of upland and wetland shrubs and herbaceous vegetation. Three habitat types were identified at the site: scoured rocky woodland, alluvial terrace forest, and island rock outcrop. Collections were made bimonthly through the growing season. A total of 195 species representing 162 genera and 80 families were collected. Of this total, 20.5 % were introduced non-native species. Ten species rare in Maryland were found.

Introduction

The Potomac River riparian corridor has complex geology and rich biodiversity in a densely populated setting convenient to many natural resource professionals and students (Cohn 2004). Early authors noted plant diversity in the Potomac River Gorge (Ward 1881; Hitchcock and Standley 1919). However, there have been relatively few Potomac River botanical studies published since the early 1970's (Terrell 1970, Grimshaw and Bradley 1973). The most useful and recent descriptions of plant communities in the Potomac River Gorge are found in Lea and Frye (2002). A study by Pyle (1995) examined the effects of disturbance on exotic plant species in the Potomac River floodplain. The study was not a comprehensive inventory, but it did capture forest community composition and relative abundance of many species on Ruppert Island. Johnston and Winings (1987) documented the decline of breeding birds at study sites along the Potomac, and noted dominant tree species on Plummers Island. Everson and Boucher (1998) explored the relationship of tree species richness to Potomac floodplain width and topographic complexity at sites near Shepherdstown, WV. Steury and Davis (2003) recently made extensive collections along the Potomac River in Maryland below the Fall Line, but their results better describe Coastal Plain habitats than those found in the Potomac River Gorge.

As rapid urban development eliminates natural vegetation from the Potomac watershed, protected areas in the Potomac River Gorge serve as an important refuge for native plant species. The objectives of this study were: (1) to describe the composition of the vegetation of Minnies Island in the Potomac River Gorge; (2) to identify occurrences of state and globally rare plant species on the island; and (3) to provide information to support long-term management of the island as a nature preserve.

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Description of the Study Area

Minnies Island is a small island (~ 3 ha) located in the Potomac River in the Potomac River Gorge. The Potomac River Gorge is a Fall Line gorge where resistant bedrock creates rapids and falls as current drops from the Piedmont onto the Costal Plain (Lea and Frye 2002). Minnies Island is located near the town of Cabin John, in southern Montgomery County, Maryland, about 3 km northwest of Washington, DC. Minnies Island is within the northern part of the Southeastern Mixed Forest Province ecoregion, also known as the Piedmont (Bailey 1995). Climax vegetation in the Piedmont is forest featuring a mix of broadleaf deciduous and needleleaf evergreen trees (Bailey 1995). However, vegetation in the vicinity of the study area has been converted to suburban development dissected by a few corridors of natural vegetation. The temperate Piedmont climate features hot, humid summers and mild winters. The mean winter temperature in Washington, DC during the past 40 years has been 1.2 °C, and mean summer temperature has been 23.2 °C (National Climatic Data Center 2004). The average frost-free period is 190 days (Pickering 2004).

Minnies Island is privately owned, but it borders the Chesapeake and Ohio Canal National Historic Park and is accessible from the canal towpath. The island is known to have been inhabited seasonally from the 1920's to the mid 1980's. The family of Wisconsin Congressman Henry Reuss owned Minnies Island from the 1960's until 1994, when Margaret and Christopher Reuss donated the island to the Potomac Conservancy. The Potomac Conservancy, a regional non-profit environmental organization, has been managing the island as a nature preserve and outdoor education center. The flora of the island has undergone some anthropogenic manipulation in the past. The island's previous owners likely planted several introduced ornamental species. In addition, Potomac Conservancy land stewards have created a native plant landscaping demonstration area by planting some native plants around a small cabin that stands on a rock outcrop on the highest point of the island. Beginning in 1999 they have also conducted yearly invasive species removal projects to control introduced smothering vines (*Celastrus orbiculatus* and *Vinca minor*).

Minnies Island is approximately 300 m long and 100 m wide at its widest point. The study site is a 3 ha complex of xeric rock outcrops, well-drained alluvial floodplain forest, and frequently flooded rock beds that support dense woody vegetation. Most of the island is 15 m above msl, with rock outcrops several meters higher, and rocky scoured areas several meters lower. The island alluvial terrace is eroding, and photographic evidence suggests that the alluvial terrace was wider before 1972 when a flood associated with Hurricane Agnes swept through the Potomac River Gorge.

The Montgomery County Soil Survey delineates Rock Outcrop-Blocktown complex soils on Minnies Island (Natural Resources Conservation Service 1995). Blocktown channery silt loam soil occurs in between areas of rock outcrops. Blocktown series soils are yellow-red, loamy-skeletal, mixed, mesic, shallow Typic Hapludults. These soils are usually shallow, well drained, and formed from material weathered from phyllite and schist. However, most of Minnies Island is not xeric rock outcrop. Soils on the flat, occasionally flooded terraces on Minnies Island best matched the description of alluvial Lindside silt loam, which is reported from islands

downstream. Lindside series soils are fine-silty, mixed, mesic Fluvaquentic Eutrochrepts found on flood plains. This moderately well drained brown silt loam is derived from alluvium washed mostly from lime-influenced soils. (Natural Resources Conservation Service 1995).

Geologic features underlying islands and floodplains in the vicinity of the study area are Cenozoic surficial deposits, Holocene alluvium, unconsolidated clay, silt, sand, and gravel. Island rock outcrops are metamorphic rock dating back to the Lower Cambrian belonging to the Sykesville Formation. Outcrops are gray, quartzo-feldspathic matrix with fragments and bodies of metamorphosed sedimentary, volcanic, and igneous rocks (Southworth et al. 2001).

Methods

Bimonthly visits to Minnies Island were made between March 9 and October 13, 2002 to collect voucher specimens of vascular plants. A kayak was used to paddle to the island when river levels were high; otherwise it was possible to wade to the island from the C&O Canal towpath. Alluvial terrace forest, island rock outcrop, and rocky scoured woodland habitats were searched during each visit. Species were identified using Gleason and Cronquist (1991) with Holmgren (1998). Christopher Frye of the Maryland Department of Natural Resources provided assistance with some determinations, particularly rare species tracked by the Maryland Wildlife and Heritage Service. Voucher specimens of all species collected were deposited in the National Arboretum Herbarium (NA), in Washington, DC.

Results

The nearest United States Geologic Survey (USGS) river gauge on the Potomac is at Little Falls, Maryland (Station 01646500). River levels at Little Falls USGS Station were between 0.6 and 2.0 m (2.0 and 6.5 feet) during March to October (United States Geologic Survey 2004). Flood stage is 3 m (10 feet). River levels in 2002 were near mean levels during spring 2002, but mostly lower than mean levels in summer and early fall 2002. Weather conditions in the year 2002 were slightly warmer and drier than average. Mean annual temperature for 2002 in Washington, DC was 13.3 °C, which was slightly above the annual mean temperature of 12.3 °C. The recorded yearly total precipitation for 2002 was 97.5 cm, which was slightly below the annual mean yearly total precipitation of 104.7 cm (National Climatic Data Center 2004).

During the period March 9 to October 13, 2002, 195 species representing 162 genera and 80 plant families were collected from Minnies Island. The plant families with the greatest number of species were Asteraceae (25 species), Poaceae (12), Liliaceae (9), Lamiaceae (8), Brassicaceae (7), and Ranunculaceae (7). *Toxicodendron radicans* and *Acer negundo* were observed but not collected. Collections also did not include several native herbs and one *Sambucus canadensis* shrub that had been planted in a flowerbed adjacent to the cabin. Collecting these species would have been destructive to the Potomac Conservancy's native plant landscaping demonstration garden. Out of 195 species, 40 species (20.5 %) were introduced non-native plants. The majority of introduced species were collected in alluvial terrace forest habitat.

Three habitat types were observed at the study site: alluvial terrace forest, island rock outcrop, and rocky scoured woodland. There were 110 species collected from alluvial terrace forest habitat, 30 from island rock outcrop habitat, and 47 from rocky scoured woodland habitat. Only 8 species were abundant in more than one habitat type.

Alluvial terrace forest grew on a seldom flooded, well-drained floodplain bench several meters above mean river level. Although 18 different species of mature trees were observed, no one species was dominant. *Fraxinus pennsylvanica*, *Platanus occidentalis*, *Acer saccharinum*, and *Liriodendron tulipifera* were common. There were other hardwood trees such as *Prunus serotina*, *Quercus rubra*, *Tilia americana*, *Nyssa sylvatica*, and *Fagus grandifolia* that were present only as one or two mature individuals. Seedling and sapling age hardwood trees were rare. This may have been a function of beaver and deer herbivory, flooding, or the effect of heavy shade from the dense shrub layer. Dominance in the shrub layer was shared by *Lindera benzoin*, *Staphylea trifolia*, and *Asimina triloba*. Climbing vines *Smilax rotundifolia*, *Dioscorea villosa*, *Parthenocissus quinquefolia*, *Menispermum canadense*, and introduced vines *Celastrus orbiculatus* and *Ampelopsis brevipedunculata* used shrubs and small trees for support. Spring ephemeral wildflower species were abundant in the herbaceous layer of the alluvial terrace forest. *Mertensia virginica*, *Cardamine concatenata*, *Senecio aureus*, *Podophyllum peltatum*, and *Erythronium americanum* blanketed the ground in April. Later in the growing season, *Polygonum virginianum*, *Solidago gigantea*, *Phytolacca americana*, *Helianthus decapetalus*, *Verbesina alternifolia*, and *Polymnia uvedelia* were dominant in partial shade to sun, especially along the south-facing river bank.

Island rock outcrop habitat was limited to a small portion of the western (upstream) end of the island. Minnie's Island outcrops are relatively eroded, steep-sided, and mostly lack the flat substrate of species-rich xeric bedrock terraces known from islands further upstream. The island rock outcrops occupy a small portion of the island and are best described as outcrops in a matrix of floodplain forest. Some potential rock outcrop habitat had been eliminated years ago by the cabin that sits on an outcrop on the highest point of the island. Island rock outcrop habitat supported few large trees (one mature *Quercus alba* was an exception) but had abundant woody vegetation in the form of small trees and shrubs. *Viburnum prunifolium*, *Juniperus virginiana*, and *Amelanchier arborea* were common. The introduced shrub *Lonicera maackii* was established on the north side of the outcrops and had resprouted vigorously after being cut back in 2001. *Toxicodendron radicans* cover was dense on outcrops. Some unexpected finds included *Dirca palustris*, *Ptelea trifoliata* var. *mollis*, and *Clematis viorna*, all three species are on the Maryland rare plant list. Herbaceous cover grew from cracks and small pockets of soil among outcrop boulders. Although unable to exploit as much habitat as shrubs and vines, some notable herbaceous species collected were *Solidago puberula*, *Polypodium virginianum*, *Heuchera americana*, *Saxifraga virginiensis*, and *Arabis laevigata*.

Rocky scoured woodland habitat occurred below the alluvial terrace on frequently flooded rocky shelves with substrate grading into the riverbed. Scoured woodlands were dominated by flood-tolerant trees and shrubs. Woody species observed were *Dyospyros virginiana*, *Ulmus americana*, *Betula nigra*, *Salix nigra*, *Acer*

negundo, and *Cornus amomum*. Several *Quercus bicolor* had been reduced to stumps by beaver. *Justicia americana* was abundant in submerged areas, sometimes growing with *Hibiscus laevis*. *Eupatorium serotinum* was the dominant herbaceous species growing in sand and silt on higher ground. Summer wildflowers, *Eupatorium coelestinum*, *Mimulus ringens*, *Verbena hastata*, *Teucrium canadense*, *Lysimachia ciliata*, and *Vernonia noveboracensis* were frequently observed. The grasses *Elymus villosus* and *Chasmanthium latifolium* were common, and the introduced species, *Artemisia annua* and *Lespedeza cuneata*, grew in limited but dense patches.

Ten species considered rare in Maryland were collected on Minnies Island (Maryland Department of Natural Resources 2001). No federally listed species were observed. Only one species, *Phacelia covillei*, had been ranked globally rare (G2 S1) and listed Endangered in Maryland. This short-statured herb was not scarce in well-drained alluvial terrace forest habitat, but it could be easily overlooked because of its size and similar appearance to the common introduced groundcover *Veronica hederaefolia*. *Phacelia covillei* was most easily identified in late April. Other Maryland-listed species, *Rumex altissimus* (Endangered), and two *Dirca palustris* shrubs (Threatened) were also observed. Other collected species listed rare in Maryland were *Arabis hirsuta* var. *adpressipilis*, *Clematis viorna*, *Cyperus refractus*, *Hibiscus laevis*, *Ptelea trifoliata* var. *mollis*, *Silphium trifoliatum* var. *trifoliatum*, and *Zizia aurea*. Also collected was *Veronicastrum virginicum*, which is under review for inclusion on the Maryland rare plant list.

Discussion

Over 1400 plant species grow in the Potomac River Gorge, and recent botanical surveys in the gorge have yielded collections of nearly 300 rare species of the Mid-Atlantic region (Cohn 2004). Many of these species are common in other parts of North America; disjunct populations persist in the river gorge. Over 100 state rare species have been collected from the Maryland side of the gorge alone (Lea and Frye 2002). Rare plant collections from Minnies Island contribute to a better overall understanding of biodiversity in the region, and highlight the importance of conserving small island habitats in the Potomac River Gorge.

Plant diversity on Minnies Island could be a function of island shape and soil drainage. In a study of Potomac river floodplain tree diversity, Everson and Boucher (1998) observed a significant negative relationship between tree species richness and width of the riparian zone along the Potomac River. Narrow, well-lit, riparian zones adjacent to water with stable, well-drained soils had higher species richness than wide river floodplains with frequently saturated soils. Plant diversity observed on Minnies Island was consistent with these results. Minnies Island's species richness could be a function of its shape (long and narrow) and good drainage in its infrequently flooded alluvial terrace soils.

Minnies Island is protected from the type of urban development that has eliminated natural areas throughout the Washington, D.C. metropolitan area, but the island is far from safe from all threats. Introduced plant species are strong competitors and may represent a threat to native plants. As many as 273 introduced species have

become established in the Potomac River Gorge (Cohn 2004). The most abundant introduced species on Minnies Island were the vines *Celastrus orbiculatus*, *Ampelopsis brevipedunculata*, and *Vinca minor*. These species were observed smothering and out-competing native herbs and shrubs. Introduced species accounted for 20.5 % of the species richness on Minnies Island. A similar result was found in collections downstream along the Potomac in Piscataway and Fort Washington National Parks where introduced species accounted for 25.3% of species richness (Steury and Davis 2003). Yearly maintenance could be needed in perpetuity to prevent invasive introduced plants from dominating Minnies Island flora.

Total eradication of introduced plants is unlikely because flood waters bring seeds to Minnies Island from elsewhere in the Potomac River riparian corridor. Two introduced species, *Polygonum cuspidatum* and *Gleditsia triacanthos*, were found growing on recently exposed riverbank. (Some authors, including Isley (1998), consider *Gleditsia triacanthos* not native to the Piedmont ecoregion in Maryland, but instead native to central North America and having spread eastward during European settlement.) These individuals growing on the riverbank were most likely delivered as seed by high water. Survey efforts during the growing season also revealed there were many native species that persisted only as one small patch or a single tree. A catastrophic event could easily wipe out several of the island's species. These observed colonizations, considered with the potential for localized extinction suggests that the flora of Minnies Island is far from stable. Long-term species composition on the island could be a function of many external factors not addressed in this study, including seed banks, flood events, and drinking water withdrawals from the Potomac River. Further study on Minnies Island and other islands in the Potomac River Gorge would lead to a better understanding of how to protect the biodiversity of this dynamic ecosystem.

Annotated Checklist of Taxa

Most nomenclature follows Gleason and Cronquist (1991). Families and genera are arranged alphabetically within classes. Common name and collection number follow the scientific name for each species. An asterisk precedes introduced species (*), and species rare in Maryland are followed by the letter R. Abbreviations for habitat types are ATF = alluvial terrace forest, IRO = island rock outcrop, and RSW = rocky scoured woodland. All vouchers have been deposited in the National Arboretum Herbarium (NA), Washington, DC.

POLYPODIOPHYTA

ASPLENIACEAE

Asplenium platyneuron (L.) Oakes (Maidenhair spleenwort), 146; IRO.

Polystichum acrostichoides (Michx.) Schott (Christmas fern), 96; IRO.

Cystopteris protrusa (Weatherby) Blasdell (Lowland bladder-fern), 86; IRO.

ONOCLEACEAE

Onoclea sensibilis L. (Sensitive fern), 212; ATF.

POLYPODIACEAE

Polypodium virginianum L. (Common polypody fern), 101; IRO.

PINOPHYTA

CUPRESSACEAE

Juniperus virginiana L. (Red cedar), 71; IRO.

MAGNOLIOPHYTA (MAGNOLIOPSIDA)

ACANTHACEAE

Justicia americana (L.) M. Vahl (Water willow), 214; RSW.

ACERACEAE

Acer saccharinum L. (Silver maple), 73; ATF.

Acer saccharum Marshall (Sugar maple), 65; ATF, IRO.

ANNONACEAE

Asimina triloba (L.) Dunal. (Paw paw), 53, 64; ATF.

APIACEAE

**Conium maculatum* L. (Poison hemlock), 61; ATF.

Zizia aurea (L.) Koch (Golden alexanders), 226, R; RSW.

APOCYNACEAE

Apocynum cannabinum L. (Hemp dogbane), 211; RSW.

**Vinca minor* L. (Periwinkle), 21; ATF.

ARISTOLOCHIACEAE

Asarum canadense L. (Wild ginger), 52; ATF.

ASCLEPIADACEAE

Asclepias incarnata L. (Swamp milkweed), 124; ATF.

ASTERACEAE

**Artemisia annua* L. (Annual wormwood), 182; RSW.

Aster cordifolius L. (Common blue heart-leaved aster), 228; ATF.

Aster divaricatus L. (Woodland aster), 174; IRO.

Aster lateriflorus (L.) Britton (Goblet aster), 185; ATF.

Bidens vulgata Greene (Tall beggar-ticks), 194; ATF.

Conyza canadensis (L.) Cronq. (Horseweed), 178; ATF.

Erigeron strigosus Muhl. (Rough fleabane), 112; ATF.

Eupatorium coelestinum L. (Mistflower), 109; RSW.

Eupatorium fistulosum Barratt (Hollow-stemmed joe pye weed), 119; RSW.

Eupatorium rugosum Houttuyn (White snakeroot), 177; ATF.

Eupatorium serotinum Michx. (Late eupatorium), 168; RSW.

Helenium autumnale L. (Common sneezeweed), 165; RSW.

Helianthus decapetalus L. (Forest sunflower), 159; ATF.

Polymnia uvedelia L. (Yellow-flowered leaf-cup), 157; ATF.

Senecio aureus L. (Heart-leaved groundsel), 25, 43; ATF.

Silphium trifoliatum L. var. *trifoliatum* L. (Whorled rosin-weed), 223, R; IRO.

Solidago caesia L. (Wreath goldenrod), 184; IRO.

Solidago flexicaulis L. (Zig-zag goldenrod), 189; IRO.

Solidago gigantea Aiton (Smooth goldenrod), 169; ATF.

Solidago puberula Nutt. (Dusty goldenrod), 180; IRO.

Solidago rugosa Miller (Wrinkle-leaved goldenrod), 170; ATF.

Taraxacum officinale Weber ex Wiggers. (Common dandelion), 40; ATF.
Verbesina alternifolia (L.) Britton (Wingstem), 164; ATF.
Vernonia noveboracensis (L.) Michx. (New York ironweed), 151; RSW.
Xanthium strumarium L. (Common cocklebur), 186; RSW.

BERBERIDACEAE
Podophyllum peltatum L. (May apple), 38; ATF.

BETULACEAE
Betula nigra L. (River birch), 56; RSW
Carpinus caroliniana Walter (Ironwood), 92, 125; ATF.

BIGNONIACEAE
Campsis radicans (L.) Seemann (Trumpet creeper), 132; IRO.
Catalpa speciosa Warder (Northern catalpa), 195; ATF.

BORAGINACEAE
Mertensia virginica L. (Eastern bluebells), 32, 45; ATF.

BRASSICACEAE
**Alliaria petiolata* (Bieb.) Cavara & Grande (Garlic mustard), 37; ATF.
Arabis laevigata (Muhl.) Poiret (Rock cress), 44; IRO.
Arabis hirsuta L. var. *adpressipilis* (M. Hopkins) (Rock cress), 217, R; ATF.
Cardamine concatenata (Michx.) O. Schwarz. (Five-parted toothwort), 30; ATF.
**Cardamine hirsuta* L. (Hoary bitter-cress), 42; ATF.
**Hesperis matronalis* L. (Dames rocket), 84; ATF.
**Thlaspi perfoliatum* L. (Thoroughwort penny-cress), 41; ATF.

CAESALPINIACEAE
Cercis canadensis L. (Redbud), 33; ATF.
**Gleditsia triacanthos* L. (Honey locust), 210; RSW.

CAMPANULACEAE
Lobelia cardinalis L. (Cardinal flower), 148; RSW.
Lobelia inflata L. (Indian tobacco), 149; RSW.
Lobelia siphilitica L. (Blue lobelia), 193; RSW.

CAPRIFOLIACEAE
**Lonicera japonica* Thunb. (Japanese honeysuckle), 76; ATF, IRO.
**Lonicera maackii* (Rupr.) Maxim (Bush honeysuckle), 95; ATF, IRO.
Viburnum prunifolium L. (Black haw), 55; IRO.

CARYOPHYLLACEAE
**Saponaria officinalis* L. (Bouncing bet), 208; ATF.
**Stellaria media* (L.) Villars (Common chickweed), 24; ATF.

CELASTRACEAE
**Celastrus orbiculatus* Thunb. (Oriental bittersweet), 46, 81; ATF.
Euonymus americanus L. (Strawberry-bush), 70; IRO.

CLUSIACEAE
Hypericum mutilum L. (St. John's-wort), 167; RSW.

CONVOLVULACEAE
Ipomea pandurata (L.) G. Meyer (Wild potato), 113; ATF.

CORNACEAE
Cornus amomum Miller (Silky dogwood), 121; RSW.
Nyssa sylvatica Marshall (Black gum), 98; ATF.

EBENACEAE

Diospyros virginiana L. (Persimmon), 131; RSW.

EUPHORBIACEAE

Acalypha rhomboidea Raf. (Rhombic copperleaf), 175; ATF.

FABACEAE

Desmodium glabellum (Michx.) DC. (Tick trefoil), 106, 141; ATF.

**Lespedeza cuneata* (Dum. Cours.) G. Don (Sericea lespedeza), 153, 172; RSW.

**Melilotus alba* Medikus (White sweet clover), 134; RSW.

Robinia pseudoacacia L. (Black locust), 72; ATF.

**Styphnolobium japonicum* (L.) Schott = *Sophora japonica* (Pagoda tree), 179; ATF.

FAGACEAE

Fagus grandifolia Ehrh. (American beech), 67; ATF.

Quercus alba L. (White oak), 57; IRO.

Quercus bicolor Willd. (Swamp white oak), 142, 183; RSW.

Quercus rubra L. (Northern red oak), 66; ATF.

FUMARIACEAE

Corydalis flavula (Raf.) DC. (Short-spurred corydalis), 49; ATF.

Dicentra cucullaria (L.) Bernh. (Dutchman's breeches), 31; ATF.

GERANIACEAE

Geranium maculatum L. (Wild geranium), 54; ATF.

HYDRANGEACEAE

Hydrangea aborescens L. (Wild hydrangea), 198; IRO.

HYDROPHYLLACEAE

Phacelia covillei S. Watson ex A. Gray (Phacelia), 221, R; ATF.

JUGLANDACEAE

Carya cordiformis (Wangenh.) K. Koch. (Bitternut hickory), 188; ATF.

Carya tomentosa (Poiret) Nutt. (Mockernut hickory), 93; ATF.

Juglans nigra L. (Black walnut), 203; ATF.

LAMIACEAE

Collinsonia canadensis L. (Northern horse-balm), 147; ATF.

**Glechoma hederacea* L. (Gill-over-the-ground), 36; ATF.

**Lamium purpureum* L. (Red dead nettle), 35; ATF.

**Leonurus marrubiastrum* L. (Horehound-motherwort), 160; ATF.

Physostegia virginiana (L.) Benth. (Obediance), 115; RSW.

**Prunella vulgaris* L. (Self-heal), 150; ATF.

Salvia lyrata L. (Sage), 85; ATF.

Teucrium canadense L. (American germander), 123; RSW.

LAURACEAE

Lindera benzoin (L.) Blume (Spicebush), 27; ATF.

MALVACEAE

Hibiscus laevis All. (Smooth rose-mallow), 220, R; RSW.

MIMOSACEAE

**Albizia julibrissin* Durazz. (Mimosa), 74; RSW.

MENISPERMACEAE

Menispermum canadense L. (Moonseed), 128; ATF.

MAGNOLIACEAE
Liriodendron tulipifera L. (Yellow poplar), 205; ATF.
OLEACEAE
Chionanthus virginicus L. (Fringe tree), 99; IRO.
**Forsythia suspensa* (Thunb.) Vahl (Forsythia) 26; ATF.
Fraxinus pennsylvanica Marshall (Green ash), 103; ATF.
**Ligustrum obtusifolium* L. (Privet), 75; ATF.
ONAGRACEAE
Oenothera biennis L. (Common evening-primrose), 166; ATF.
OROBANCHACEAE
Orobanche uniflora L. (Cancer root), 100; IRO.
OXALIDACEAE
Oxalis stricta L. (Common yellow wood sorrell), 213; ATF.
PAPAVERACEAE
Sanguinaria canadensis L. (Bloodroot), 29; ATF.
PASSIFLORACEAE
Passiflora lutea L. (Passion flower), 161; ATF.
PHYTOLACCACEAE
Phytolacca americana L. (Pokeweed), 133; ATF.
PLATANACEAE
Platanus occidentalis L. (Sycamore), 69; ATF, IRO.
POLEMONIACEAE
Phlox divaricata L. (Forest phlox), 51; ATF.
Phlox paniculata L. (Summer phlox), 116; RSW.
POLYGONACEAE
**Polygonum cespitosum* Blume (Knotweed), 192; RSW.
**Polygonum cuspidatum* Sieb. & Zucc. (Japanese knotweed), 197; ATF.
Polygonum pensylvanicum L. (Pennsylvania smartweed), 108; ATF.
Polygonum virginianum L. (Jumpseed), 130, 156, 173; ATF.
Rumex altissimus A. Wood (Pale dock), 224, R; ATF.
**Rumex conglomeratus* Murray (Dock), 110; ATF.
PORTULACACEAE
Claytonia virginica L. (Spring beauty), 20; ATF.
PRIMULACEAE
Lysimachia ciliata L. (Fringed loosestrife), 122; RSW.
RANUNCULACEAE
Anemone quinquefolia L. (Wood anemone), 50; ATF.
**Clematis terniflora* DC. (Yam-leaved clematis), 176; ATF.
Clematis viorna L. (Leatherflower), 218, R; IRO.
Cimicifuga racemosa (L.) Nutt. (Black cohosh), 196; ATF.
Ranunculus abortivus L. (Small-flowered crowfoot), 87; IRO.
Thalictrum dioicum L. (Early meadow-rue), 144; ATF.
Thalictrum pubescens Pursh. (Tall meadow-rue), 80; ATF.
ROSACEAE
Amelanchier arborea (Michx. f.) Fern. (Downy serviceberry), 230, 231; IRO.
Geum canadense Jacq. (White avens), 135; ATF.

Prunus serotina Ehrh. (Black cherry), 94; IRO.
**Rosa multiflora* Thunb. (Multiflora rose), 58; ATF.
Rubus enslenii Tratt (Sothern dewberry), 138; IRO.
Rubus phoenicolasius Maxim (Wineberry), 59; ATF.

RUBIACEAE
Cephalanthus occidentalis L. (Buttonbush), 120; RSW.

RUTACEAE
Ptelea trifoliata L. var. *mollis* T&G (Common hop-tree), 202, 225, R; IRO.

SALICACEAE
Salix nigra Marshall (Black willow), 114; RSW.

SAURURACEAE
Saururus cernuus L. (Lizards tail), 173; RSW.

SAXIFRAGACEAE
Heuchera americana L. (Common alum root), 60; IRO.
Saxifraga virginiensis Michx. (Early saxifrage), 23; IRO.

SCROPHULARIACEAE
Mimulus ringens L. (Common monkey flower), 155; RSW.
**Verbascum blattaria* L. (Moth-mullein), 163; ATF.
**Veronica hederaefolia* L. (Ivy-leaved speedwell), 22; ATF.
Veronicastrum virginicum (L.) Farw. (Culvers root), 222; IRO.

SIMAROUBACEAE
Ailanthus altissima (Miller) Swingle (Tree of heaven), 91; ATF, IRO.

SOLANACEAE
Datura stramonium L. (Jimson weed), 152; RSW.
Solanum carolinense L. (Horse nettle), 207; ATF.

STAPHYLEACEAE
Staphylea trifolia L. (Bladder-nut), 47, 78; ATF.

TILIACEAE
Tilia americana L. (Basswood), 68; ATF.

THYMELAEACEAE
Dirca palustris L. (Leatherwood), 216, 219, R; ATF, IRO.

ULMACEAE
Celtis occidentalis L. (Hackberry), 79; ATF.
Ulmus americana L. (American elm), 34; RSW.

URTICACEAE
Boehmeria cylindrica (L.) Swartz (False nettle), 191; RSW.
**Urtica dioica* L. (Stinging nettle), 126; ATF.

VALERIANACEAE
**Valerianella locusta* (L.) Betcke. (Blue corn salad), 89; ATF.

VERBENACEAE
Phyla lanceolata (Michx.) Greene (Lippia), 158; RSW.
Verbena hastata L. (Blue vervain), 162; RSW.
Verbena urticifolia L. (White vervain), 136; RSW.

VIOLACEAE
Viola sororia Willd. (Common blue violet), 39; ATF, RSW.

VITACEAE

**Ampelopsis brevipecundulata* (Maxim.) Trautv. (Porcelain-berry), 129; ATF.

Parthenocissus quinquefolia (L.) Planchon (Virginia-creeper), 209; ATF.

MAGNOLIOPHYTA (LILIOPSIDA)

AGAVACEAE

Yucca filamentosa L. (Adam's needle), 145; ATF.

ARACEAE

Arisaema triphyllum (L.) Schott (Jack in the pulpit), 201; ATF.

COMMELINACEAE

**Commelina erecta* L. (Erect day flower), 118; ATF.

Tradescantia virginiana L. (Virginia spiderwort), 97; ATF.

CYPERACEAE

Carex pensylvanica Lam. var. *pensylvanica* (a sedge), 137; ATF.

Cyperus refractus Engelm. (a flatsedge), 215, 227, R; ATF.

Cyperus strigosus L. (False nutsedge), 104, 105; RSW.

DIOSCOREACEAE

Dioscorea villosa L. (Collic root), 200; ATF.

LILIACEAE

Allium cernuum Roth (Nodding onion), 111; RSW.

**Allium vineale* L. (Field garlic), 77, 204; ATF.

Erythronium americanum Ker Gawler (Trout-lilly), 28; ATF.

**Hemerocallis fulva* L. (Day-lilly), 206; RSW.

**Muscari comosum* (L.) Miller (Grape hyacinth), 82; ATF.

**Ornithogalum umbellatum* L. (Star of Bethlehem), 88; ATF.

Polygonatum biflorum (Walter) Elliott (Solomon's seal), 63; ATF.

Smilacina racemosa (L.) Desf. (False solomon's seal), 90; ATF.

Trillium sessile L. (Toadshade), 48; IRO.

POACEAE

Andropogon gerardii Vitman (Big bluestem), 190; IRO.

Chasmanthium latifolium (Michx.) Yates (Rriver oats), 117, 154; ATF, RSW.

Echinochloa muricata (P. Beauv.) Fern. (Barnyard grass), 181; RSW.

Elymus hystrix L. (Bottlebrush-grass), 199; ATF.

Elymus villosus Muhl. (Downy wild rye), 102; RSW.

Eragrostis frankii C. A. Meyer. (Frank's love grass), 139; RSW.

**Eragrostis pilosa* (L.) P. Beauv. (India love grass), 140; RSW.

Festuca subverticillata (Pers.) E. Alexeev (Nodding fescue), 143; ATF.

**Microstegium vimineum* (Trin.) A. Camus (Stilt grass), 127; ATF.

Panicum (*Dicanthelium*) *boscii* Poir. (a panic grass), 229; RSW.

Panicum virgatum L. (Switchgrass), 107; IRO.

Tridens flavus (L.) A. Hitchc. (Purpletop), 187; ATF.

PONTEDERIACEAE

Zosterella dubia (Jacq.) Small (Water star grass), 171; RSW.

SMILACACEAE

Smilax herbacea L. (a greenbriar), 83; ATF.

Smilax rotundifolia L. (a greenbriar), 62; ATF.

Acknowledgements

Many thanks to Matthew Logan and Matthew Berres of the Potomac Conservancy for providing access to Minnies Island and granting permission to collect specimens. Thanks also to Jennifer Schill and Nathan Wilkes of the Potomac Conservancy for their coordination and communication efforts. Christopher Frye of the Maryland Department of Natural Resources, Wildlife and Heritage Service determined rare species voucher specimens and served as a reviewer. Kevin Conrad of the National Arboretum Herbarium also provided support. Additional thanks to reviewers Larry Morse of NatureServe and Christopher Lea of the National Park Service for their constructive comments.

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